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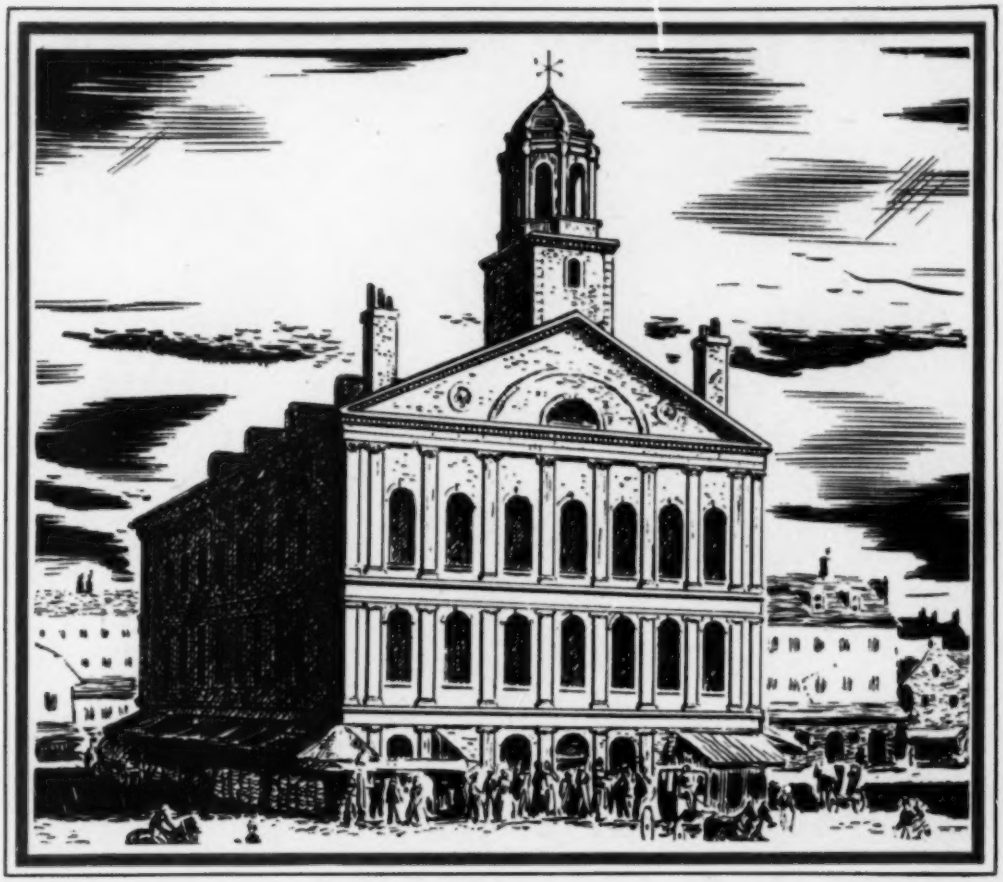

Boston's Faneuil Hall, popularly called "The Cradle of Liberty", as it looked 100 years ago.

Boston, Massachusetts, has cast iron water and gas mains in service that were installed more than a century ago. In those days, modern pavements were unknown; labor costs were low. Today, the expense of unnecessarily frequent repairs to underground mains, or untimely replacements, and consequent restoration of costly pavements, is a risk you cannot afford to gamble with. Cast iron pipe has an established record of long life and low maintenance. It effectively resists corrosion and possesses the four strength factors so necessary to meet the stresses imposed by modern traffic and crowded underground construction. These are shock, crushing, bursting and beam strengths. No pipe deficient in any of these strength factors should ever be laid in paved streets of cities, towns and villages. **United States Pipe and Foundry Co., General Offices, Burlington, N. J. Plants and Sales Offices Throughout the U. S. A.**

U.S.
CAST IRON
PIPE
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NUMBER ONE OF A SERIES

WATER & SEWAGE WORKS, April, 1952

→ For Your Water Fluoridation Program

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SODIUM SILICOFLUORIDE

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FOR AMERICAN INDUSTRY

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WATER & SEWAGE WORKS

WATER SUPPLY • SEWAGE DISPOSAL
INDUSTRIAL WASTE TREATMENT

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Treating Pharmaceutical Wastes.....Hurwitz, Edmunson & Clark
Pulaski's New Dual Purpose Softening-Filtration Plant.....Martin Johnson
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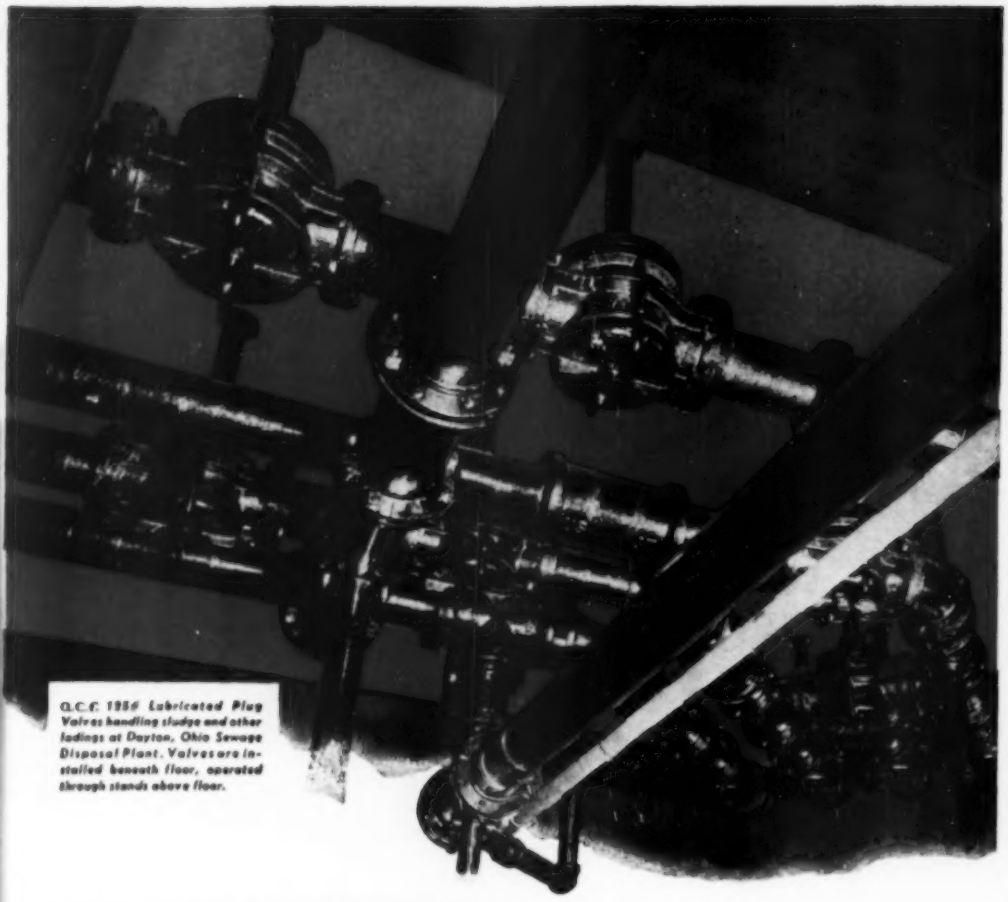

a.c.f. 1956 Lubricated Plug Valves handling sludge and other lodings at Dayton, Ohio Sewage Disposal Plant. Valves are installed beneath floor, operated through stands above floor.

NO OBSTRUCTIONS TO TRAP SOLIDS

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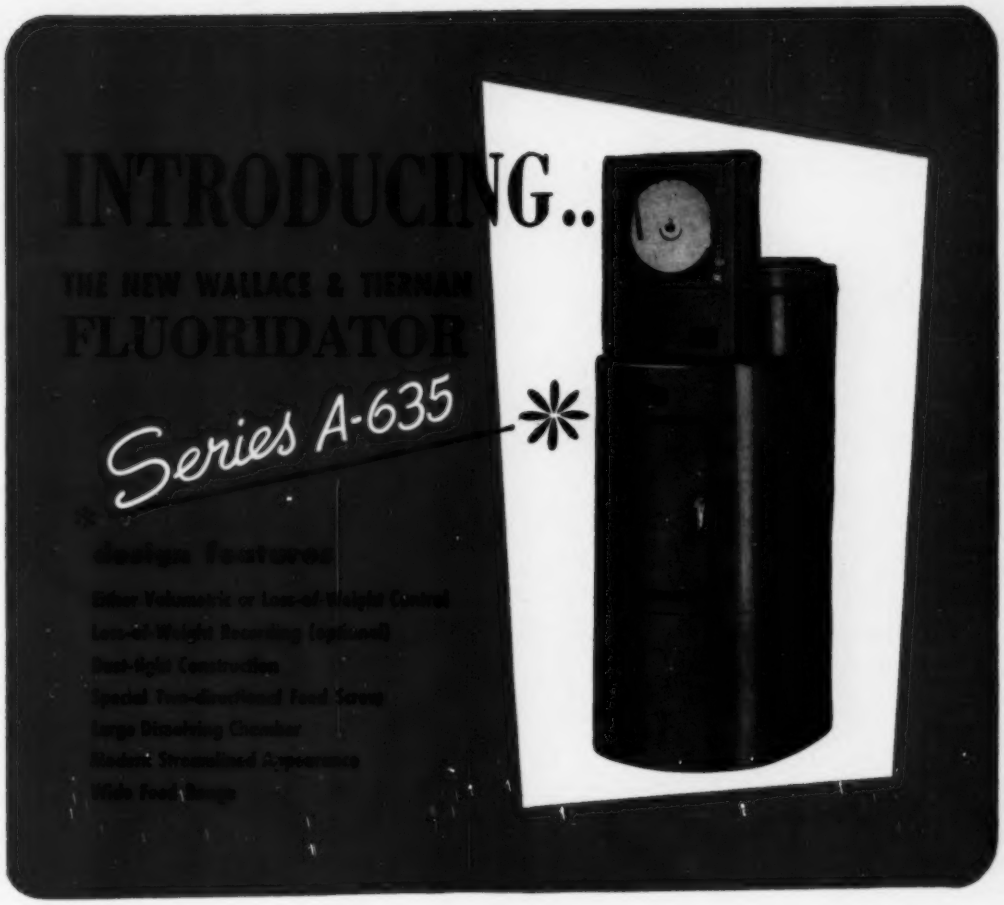
Write for Catalog 4-WS, American Car and Foundry Company, Valve Division, 1501 East Ferry Avenue, Detroit 11, Michigan



Special requirements of Fluoridation — primarily, extreme accuracy and dependability — were considered foremost in the design of W&T's new Series A-635 Fluoridator. A selection of models and a wide feed range make this feeder suitable for the application of sodium fluoride or sodium silicofluoride in most communities.

The basic feeder is volumetric with manual control, featuring the new two-directional feed screw for increased accuracy. Built-in scales can be supplied for periodic checking of the weight of chemical in the hopper.

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WALLACE & TIERNAN
COMPANY, INC.

S-47

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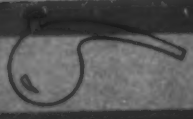

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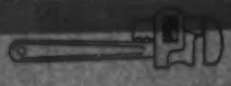

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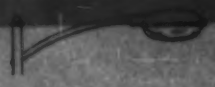

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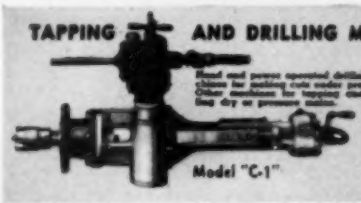
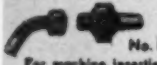


Model "C-1"

CORPORATION STOPS



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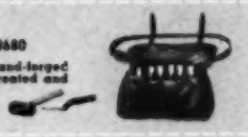

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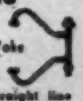

No. H-14000 Meter Yoke

Variety of meter yokes: copper yoke, single bar, straight line types, plus swivel and angle stops and test valves.

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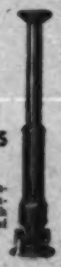
No. H-10300

Telescoping extension-type service boxes Minneapolis Pattern or Arch Pattern. Wide range of lengths and sizes.



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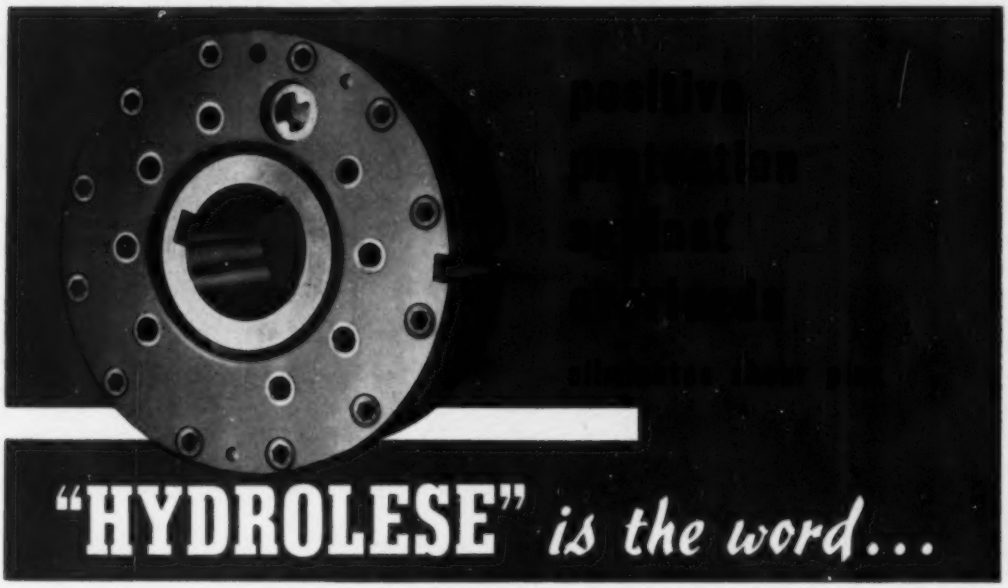
Featuring time-proved "O-Ring" seals and collision-damage-proof design.



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. . . adjusted to meet various load conditions
. . . provided with visual warning
. . . readily reset

and will not burn up. Will carry a definite torque load (maximum of 20,000 lbs.)

Let us tell you more about "HYDROLESE" Hubs and what they can do for you.

All Collectors in service at the Hyperion Sewage Treatment Works, City of Los Angeles, are HYDROLESE protected. There are 132 units in daily use at this up-to-date plant.

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Sludge Collectors
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RED RIVER ON RAMPAGE-
BJ PUMPS KEEP WORKING!

WESTERN - UNION

DRAYTON ND
BYRON JACKSON CO.
LOS ANGELES

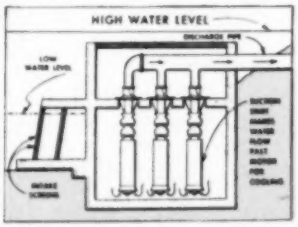
DESPITE SEVERE FLOOD CONDITIONS IN DRAYTON BYRON JACKSON SUBMERSIBLE PUMP CONTINUES IN OPERATION AND SAFE DRINKING WATER SUPPLY IS BEING MAINTAINED.

JIM ZEMAN

Along with the heart-breaking hardships brought to the many communities along the rampaging Red River, the cut-off of normal filtered water supplies added an additional problem and danger. Fortunately, the citizens of Drayton, North Dakota, were spared this further burden.

The Drayton water supply system is unique in its engineering and construction in that the Filtration Plant is located on the highest elevation in the city and a Byron Jackson Submersible Pump is used for river intake. This pump, with close-coupled, sealed motor, is designed to work completely submerged. It is unaffected by high water, ice or low water conditions which would knock out a normal surface type electric motor. City water delivery has not failed despite extreme below-zero Winter temperatures or the present severe Spring flood.

This same sure and uninterrupted water delivery can be designed for any lake or river intake installation. BJ Submersible pumps are available in capacities up to 20,000 gpm and heads to meet any intake need. Installation is simple and considerably less expensive than surface motor units. No elaborate structure is required, and no special grading of pump-to-shore pipeline is needed. Because the Submersible's pump-to-shore line is *discharge* and not suction, this line can also be smaller in diameter.



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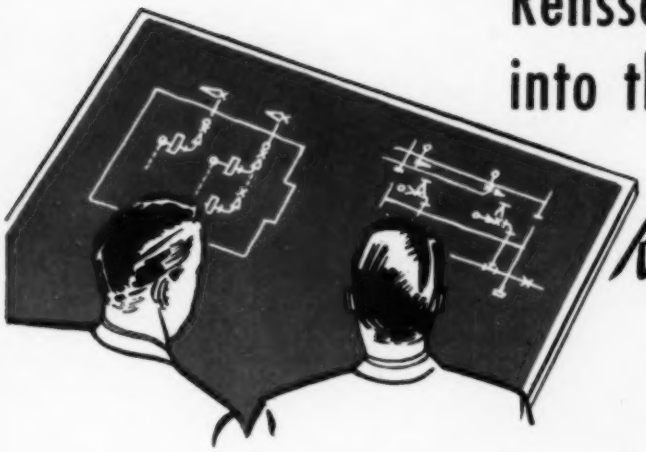
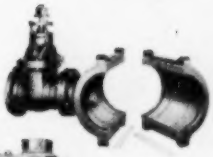


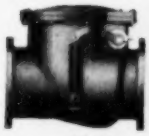
Right now!

DOUBLE DISK VALVE



TAPPING SLEEVE AND VALVE

AIR VALVE



CHECK VALVE

FIRE HYDRANT

When it's on the boards, whether it be a simple extension, or a modernization project for the entire water or sewage system, it will pay you to get the Rensselaer Engineers in at the beginning.

They know how to help plan a job for lowest equipment and piping costs—and above all, how to select from the hundreds of types and sizes available, the one valve that will do the job satisfactorily with lowest maintenance costs for more than a lifetime.

SAVE ON ORIGINAL COSTS

They will show you how a large valve assembly with a totally enclosed, permanently greased gear box can be buried without the cost of a concrete pit. They can show you why critical locations should have the square bottom valve, why the Rensselaer check valve with the adjustable spring can't slam, and even how to practically eliminate pipe line surge by an inexpensive auxiliary hook up with the check valve.

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Fire hydrants that need no digging or valve shutting for traffic accident repairs, a hydrant valve mechanism that is easily removed for inspection, and a tapping sleeve that will save hours, will help write perpetual low maintenance into your original layouts, large or small. Ask the Rensselaer man about these advantages when he calls next time.

Rensselaer VALVE COMPANY, TROY, N. Y.

GATE VALVES • FIRE HYDRANTS • SQUARE BOTTOM VALVES • CHECK VALVES • AIR RELEASE VALVES

A DIVISION OF NEPTUNE METER COMPANY

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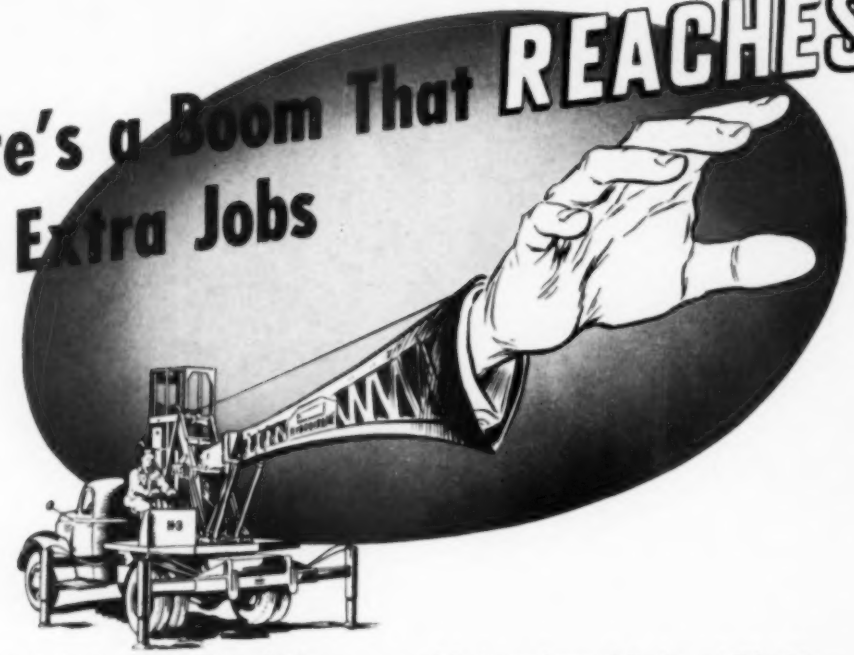
Here's a Boom That REACHES For Extra Jobs



The all-hydraulic Bucyrus-Erie 3-ton Hydrocrane with telescoping boom reaches into windows and box cars . . . over fences . . . under beams and overhanging branches . . . between wires and rafters — without moving crane an inch! Boom extends and retracts a distance of eight feet.

The outstanding advantages of telescoping boom plus precision hydraulic control and high-speed travel combine to make the Hydrocrane ideal for setting water and sewer pipe . . . digging manholes . . . emergency pipeline leak repair . . . cleaning catch basins — dozens of digging and lifting jobs.

In addition, crane can be quickly converted to hoe front-end in the field for pipe-line trenching . . . digging meter and hydrant pits . . . miscellaneous excavating. Conversion has actually been made in as little as four man-hours. See your Hydrocrane distributor for complete details.

161H52

Here the Hydrocrane cleans catch basins with special catch basin cleaner attachment. Every work function fully hydraulic — boom hoist and swing, load hoist, boom telescope, outrigger set and retract, bucket close.

BUCYRUS ERIE
HYDROCRANE
South Milwaukee, Wisconsin

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QUALITY, PRECISION AND CAREFUL DESIGN

Illustrated here, are three of our most popular items: E-3123 Corporation Stop with an eighth bend union coupling, inlet and outlet threaded to fit Mueller Machine; the E-2931 and the E-3061 Curb Stops. The last two may be obtained with stop and drain or stop only. E-3061 is furnished with combined cap and tee handle—loose tee or lever handle furnished if desired.

Write us for complete information on our entire line . . . We will gladly furnish it free. A. Y. McDonald Mfg. Co., Dubuque, Iowa.

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To Make Tight Joints That Stay Tight - - *Under Water*

USE
TYLOX
flexible-rubber
JOINTS

BREMERTON'S new sewer outfall into Puget Sound had to be laid fast and had to be laid tight — despite knee-deep water in the ditch, despite a bed of shifting sand and mud.

A fast coupling joint was needed because the line had to be laid at night — between tides. A permanently tight joint was needed to prevent the infiltration of sea water. A fully flexible joint was needed to compensate for the soil stresses. A water insensitive joint was needed because of the sopping wet beach conditions.

The engineer and contractor on the job found the answer in TYLOX flexible rubber JOINTS. They found TYLOX gaskets were easily installed and quickly coupled. They found TYLOX gaskets gave permanently tight joints. They found TYLOX gaskets flexible enough to handle practically any soil conditions. They found TYLOX gaskets did their job under the wettest conditions — under water!

You, too, will find that TYLOX JOINTS are fast, positive and permanent. They make lines "leakproof for life" on shifting soil — below ground water level — or "on radius".

On that next "tough" job, be sure — use the flexible rubber joint — use TYLOX.

Making Joints with TYLOX RUBBER GASKETS is as simple as ABC

Cement tongue and snap on Tylox gasket. Lubricate sliding surfaces with Tylox Cement. Shove the pipe home.

Night photographs of the coupling of TYLOX gasketed pipe, between tides, on the shore of Puget Sound.

THUMBNAIL FACTS ABOUT THE BREMERTON JOB

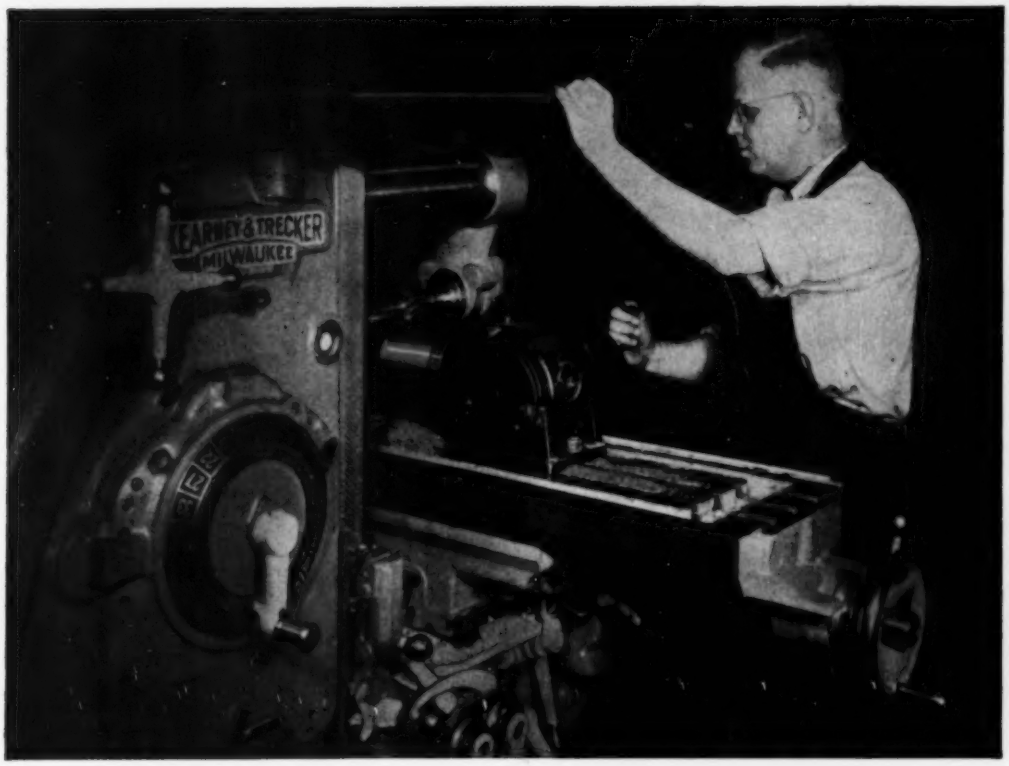
Location: Bremerton, Washington.
Pipe: 200 feet of concrete pipe, 36" x 8' SR(ASTM C-76-41) Manufactured by Bremerton Concrete Products Co., affiliate of Graystone Concrete Products Co., Seattle, Washington.
Coupling: TYLOX flexible rubber JOINTS.
Engineer: E. S. Severance, City Engineer for Bremerton, Washington.
Contractor: Joe Avery, Bremerton, Washington.

Write, wire, or phone for specifications and literature on TYLOX Gaskets.

HAMILTON KENT
MANUFACTURING COMPANY
KENT, OHIO

226 GOUGLER AVENUE **TEL. 3449**

"THE ONLY PERMANENTLY TIGHT LINES ARE LAID WITH RUBBER GASKETS"



BADGER PRECISION MEANS MORE DEPENDABLE METER SERVICE

Through every detail of production, Badger Meters are produced completely by Badger, with precision and quality controls and outstanding exclusive features that assure the peak of dependable meter service.

All types and sizes, for any water measuring job in home or industrial use, are available in the dependable Badger line: ⅝" to 4" disc meters; 2" to 12" Turbine (Current) Meters; 2" to 10" compound meters and industrial meters; special liquid (other than water) meters . . . accessories vital to efficient installation, reading and servicing . . . famous Badger Meter Testing Machines . . . all produced under Badger precision controls you can depend upon for most accurate metering, long life and lowest maintenance cost.

For complete, dependable meter service, it pays to buy Badger

"MEASURING THE WATER OF THE WORLD"

First for Accuracy • Low-Cost Maintenance • Durability • Sensitivity

BADGER *Water* METERS

BADGER METER MFG. CO., Milwaukee 10, Wis.

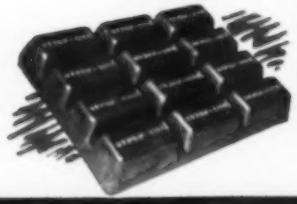
Branch Offices: New York City • Philadelphia
Worcester, Mass. • Savannah, Ga. • Cincinnati • Chicago • Kansas City • Waco, Texas
Salt Lake City, Utah • Guthrie, Okla. • Seattle, Wash. • Los Angeles

just a reminder that -

A pipeline is no better than its joints.

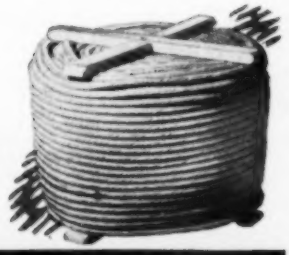
HYDRO-TITE
(POWDER)

HYDRO-TITE
(LITTLEPIGS)



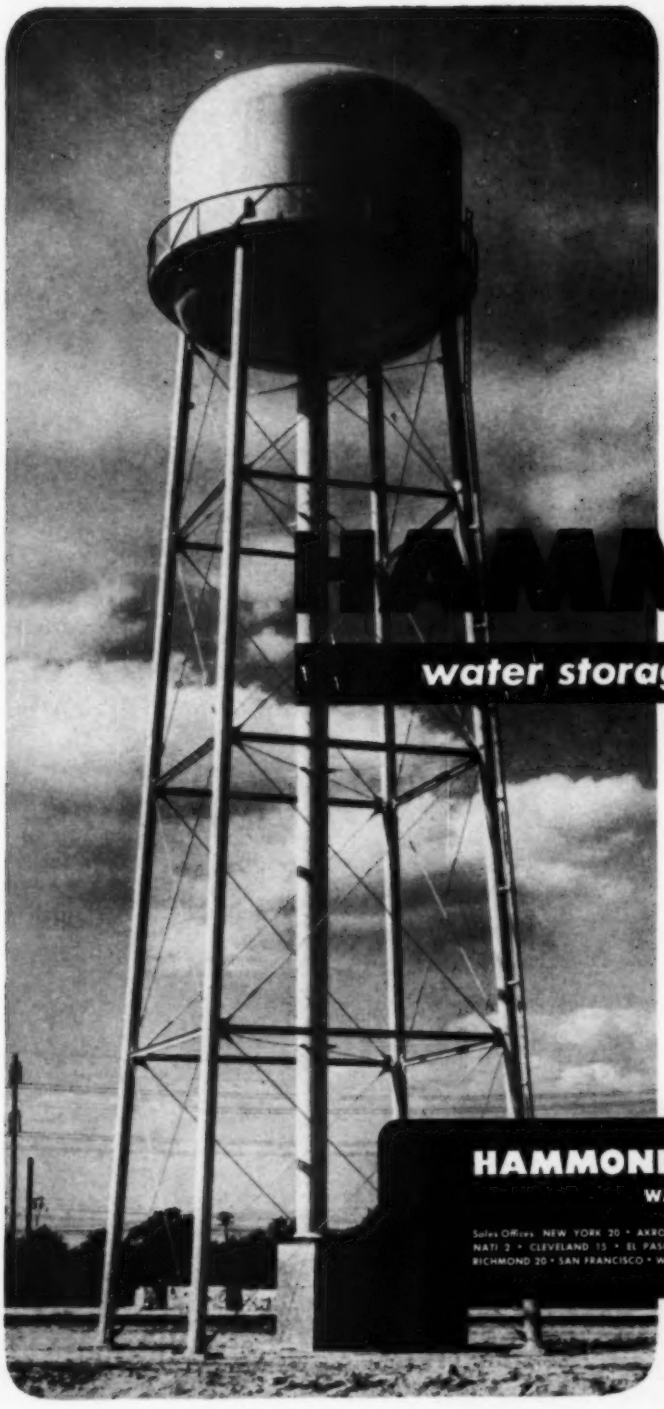
Powder or pigs—with FIBREX—make perfect joints. Working sample on request.

FIBREX
(REELS)



HYDRAULIC DEVELOPMENT CORPORATION

Main Sales Office 50 Church Street, New York General Offices and Works W. Medford Station, Boston, Mass.



HAMMOND

water storage vessels

ELEVATED TANKS, RESERVOIRS, SPHERES AND STANDPIPES

. . . built to all standard codes and specifications including: A.W.W.A. • N.B.F.U. • F.I.A. • Factory Mutual.

HAMMOND IRON WORKS

WARREN, PA. and BRISTOL, PA.

Sales Offices: NEW YORK 20 • AKRON • BOSTON 10 • BUFFALO 2 • CHICAGO 3 • CINCINNATI 2 • CLEVELAND 15 • EL PASO • HOUSTON 2 • LOS ANGELES 14 • PITTSBURGH 19 RICHMOND 20 • SAN FRANCISCO • WASHINGTON 6, D. C. • HAVANA • TIPSA • BUENOS AIRES

NEW YORK CITY

Though dwarfed by the mighty Hudson River, this modern building houses equipment to supply the city 100 million gallons of water a day. Water is screened and chlorinated at the plant before being pumped to city reservoirs.

These G-E 2500-hp, 900-rpm, 4000-volt synchronous motors drive six Peerless vertical-turbine type pumps. Although they are on "standby," the motors are ready for continuous service should New York's reservoirs become low again.

For each pump motor there is a G-E totally enclosed panel with starting, stopping, and field control.

NEW! **More Power to America Water Supply Program**

Have you seen "Pipeline to the Clouds"? This full-color movie is part of G.E.'s new MPA Water Supply Program designed to develop public interest in local water supply conditions. For further details, write on your letterhead to *General Electric Co., Sect. 666-64, Schenectady, N. Y.*

CO-ORDINATED WATER-PLANT ELECTRIFICATION

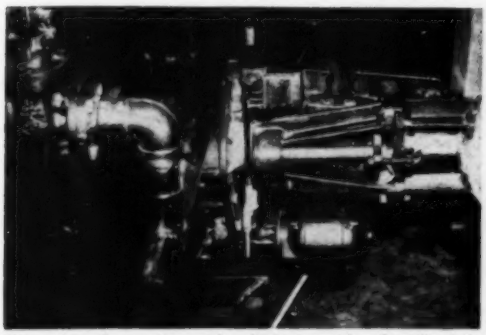
BUILDS NOW... FOR MORE WATER TOMORROW

Emergency pumping station at Chelsea, N.Y., completely G-E equipped, can supply 10 per cent of daily requirements during shortage periods

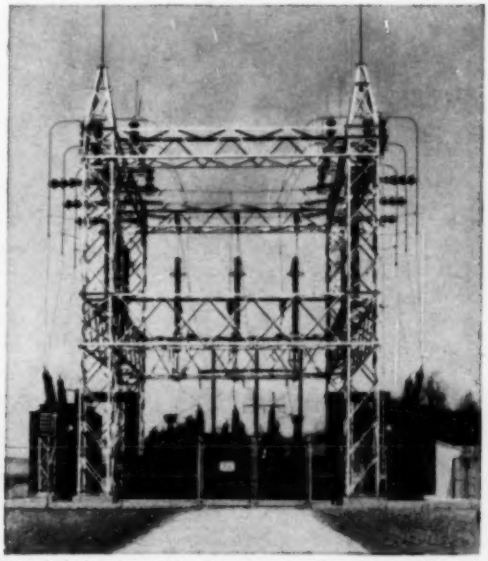
New York City's long-range plans to meet the increasing water demands of its growing population are centered on the mammoth, war-delayed Delaware Aqueduct project. The need for interim emergency provisions became apparent when the severe drought of 1949 seriously depleted city water reserves.

The 100-mgd Hudson River Pumping Station at Chelsea, N. Y., electrically equipped by General Electric, has been built to meet this temporary emergency. Now on standby duty, this station can supply a vital 10 per cent of the city's needs until completion of the first two stages of the Delaware Aqueduct. This project, now under construction and due about 1956, will make available an additional 500 million gallons of water daily.

Dependable G-E electric equipment is available for *your* water-supply expansion program. But more than that, G-E application engineers, working with your engineers and consultants, will help fit the right equipment—drives, substations, process controls—to your plant requirements. Call in your G-E representative early in the planning . . . when he can help most. *General Electric Co., Schenectady 5, N. Y.*



The gate-valve motor on the discharge side of each of the large pumps is used to close off piping for cone-valve maintenance. Other G-E motors power pumps which evacuate the wells to permit cleaning of the screens.



This G-E "packaged" substation supplies power for all station requirements, at 4160, 208, and 120 volts. Made up of factory-assembled components, these substations reduce engineering, simplify purchasing, and speed construction.

666-64

GENERAL ELECTRIC

*Transite is a registered Johns-Manville trade mark

Johns-Manville TRANSITE

TRANSITE PIPE last longer West Virginia city streets?

Transite Pipe was first installed in this West Virginia city in 1935. In addition to heavy street traffic, it has withstood soil conditions so destructive that the pipe previously used had a service life of only two to three years. When the Transite main was recently uncovered to insert a tap into the line, the pipe was found in as good condition as the day it was laid!

it's reinforced with ASBESTOS for lasting strength

THERE IS GOOD REASON why Transite* Pressure Pipe—shown in the city street above—has already far exceeded engineers' expectations for the service life of pipe used here:

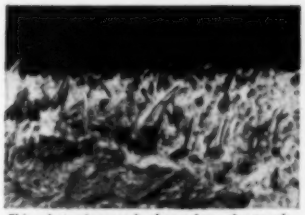
It's reinforced with tough, strong, indestructible fibers of asbestos—*the mineral that defies time!*

Countless numbers of these remarkably strong asbestos fibers—their tensile strength is comparable to that of steel—are dispersed uniformly throughout every length of Transite Pressure Pipe. This reinforced structure not only contributes to the *initial* strength needed in a pipe designed for use under busy city streets. Equally important, it helps assure the *lasting* strength that enables Transite Pipe to survive continued corrosive attack, year after year . . . to *stay* strong in service under conditions that are highly adverse to ordinary pipe materials.

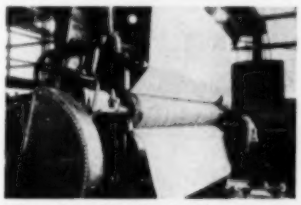
This quality of lasting strength is one of many important advantages of a pipe engineered with modern water transportation requirements in mind. Transite's Simplex Couplings reduce waterline leakage losses to a minimum, provide flexibility to help relieve the line of soil stresses and traffic loads. Its light weight makes for easier handling and effects substantial savings during installation. Its smooth interior assures a high coefficient of flow (C-140) and, because Transite can never tuberculate, helps keep pumping costs low through the years.

To find out more about how this modern asbestos-cement pipe can help solve your waterline problems and save you money, write Johns-Manville, Box 60, New York 16, N. Y.

JM PRODUCTS



This photomicrograph shows how the tough, strong asbestos fibers are distributed uniformly throughout the structure of the pipe.



On machines like this, the asbestos-cement-silica mixture is "built up" under heavy pressure into a dense, homogeneous pipe structure.

Transite's flexible Simplex Couplings help relieve the line of excessive flexural stresses—an added safeguard against pipe failures.

asbestos-cement PRESSURE PIPE

Short-cut to.....Short lengths..

CLOW Cast Iron Pipe

★ *View of Sewage Treatment Plant, Hammond, Ind. . . . one of the many plants where Clow Cast Iron Pipe in short lengths was furnished to exact specifications.*

The sanitary engineer, faced with difficult piping problems, knows the importance of short lengths of pipe. The Clow shops, completely equipped with the latest machinery run by experienced mechanics, will fabricate pipe to exact specifications. Pipe can be furnished flange and flange, flange and bell, flange and plain end or both ends plain—in all sizes 3 through 24 inches and in all laying lengths up to 18 feet.

Clow Threaded Cast Iron Pipe

Clow Cast Iron Pipe is also available in Iron Pipe Size O. D., with flanged, plain, or threaded ends. May be cut, threaded and fitted on the job or we can furnish to your exact specifications. In 3″ size—16 ft. random lengths; 4″, 5″, 6″, 8″ and 10″ sizes—18 ft. lengths.

For Cutting Cast Iron or Steel Pipe

The Clow Strickler Ratchet Pipe Cutter makes smooth, square, lathe-like cuts easily-quickly—in the field or shop. Write for Folder 8-6-51.

Strickler Ratchet Pipe Cutter

Quickly, easily cuts steel, wrought or cast iron pipe in the trench or shop. Available in five sizes for cutting pipe 2½ to 24 inches.

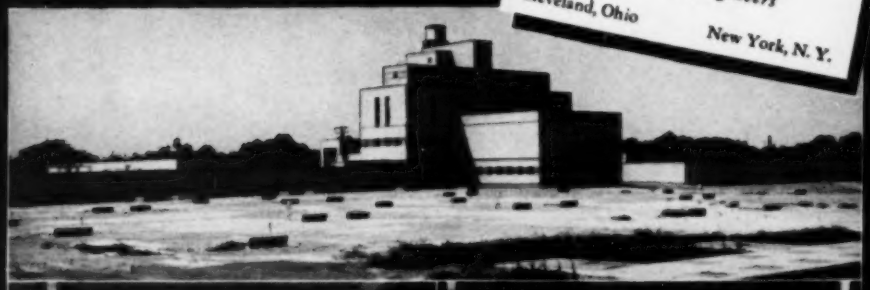
JAMES B. CLOW & SONS

201-299 North Talman Avenue • Chicago 80, Illinois

and their National Cast Iron Pipe Division, Birmingham, Alabama; subsidiaries Eddy Valve Co., Waterford, New York; Iowa Valve Co. Oskaloosa, Iowa

CLEVELAND, OHIO
Nottingham Plant
(COMPLETED IN 1951)

HAVENS & EMERSON
Consulting Engineers
Cleveland, Ohio — New York, N. Y.



Until the completion of this plant, Cleveland faced a paradoxical situation. At its doorstep was Lake Erie, an almost unlimited source of raw water, yet the city's water supply facilities were inadequate to meet the growing demands of the population. Making the Lake supply available to the citizens of Cleveland is one of the outstanding engineering feats of our day. The problems involved in building a water intake three and one-half miles out into Lake Erie, and in completing a pumping and purification plant capable of handling a daily flow of 100 MGD . . . these indeed were undertakings of enormous magnitude. The Nottingham Plant represents the fulfillment of a 25-year old dream . . . the end product of three years of construction and an expenditure of $21,000,000.

Builders-Providence, Inc. was selected to supply Venturi Meters, rate controllers, filter gauges, and other instruments for the Nottingham Plant. Installed by Pitt Construction Company, these pneumatically-operated instruments supply vital data to help John A. Marsh, Superintendent, maintain optimum efficiency of the purification process in this modern water plant. For Bulletins describing Builders Water Works Equipment, address Builders-Providence, Inc. (Division of Builders Iron Foundry), Providence 1, Rhode Island.

B-I-F Industries Equipment furnished for the Nottingham Plant:

BUILDERS

Raw Water
- **72" Venturi Meters**

Filter Equipment
- **20" Venturi Effluent Rate Controllers**
- **36" Venturi Wash Rate Controllers**
- **8" Surface Wash Meters**
- **Filter Loss and Rate Indicators**
- **Sand Expansion Indicators**
- **Control Panels, Master Control and Level Gauges**

Distribution Meters
- **24" Venturi Wash Water Meters**
- **30" Venturi Low Service Meters**
- **16" Venturi High Service Meters**
- **30" Venturi High Service Meters**
- **Control Panel, Pressure and Level Gauges**

OMEGA

Chemical Feeders
- **Omega Loss-In-Weight Gravimetric Feeders for activated carbon, alum, and lime**

B-I-F INDUSTRIES

BUILDERS PROVIDENCE *Instruments*

BUILDERS

CLAY PIPE—*ESSENTIAL* ★ *ECONOMICAL* ★ *EVERLASTING*

Tucson, Arizona, enlarges its municipal sewerage facilities in a $2 million program caused by defense expansion. Clay Pipe is specified not only for the sewerage project, but for the new electronics plant, the adjacent airport, the additional housing, and the Air Force base which made it necessary.

84 MILES OF CLAY PIPE INSTALLED IN TUCSON MUNICIPAL SEWERAGE PROJECT

Over 440,000 feet of Vitrified Clay Pipe, in sizes ranging from eight to twenty-one inches, are being installed to meet the problems posed by defense plant, airfield, and housing construction in Tucson. The defense projects, totalling over $20 million, have caused an influx of thousands of people. Vitrified Clay Pipe sewerage systems will give them the *permanent*, corrosion-proof sanitary facilities that prevent sickness and epidemics.

Clay Pipe is the *only* chemically inert pipe . . . the only pipe that's unaffected by rust, rot, decay, sewage gases, or acid action. It's the one pipe that has *proved* its resistance to chemical action through decades of actual performance in the ground. Don't take chances with non-clay materials. Specify Vitrified Clay Pipe . . . *it never wears out!*

NATIONAL CLAY PIPE MANUFACTURERS, INC.
311 High Long Bldg., 5 E. Long St., Columbus 15, Ohio
703 Ninth & Hill Bldg., Los Angeles 15, Calif.
100 N. LaSalle St., Rm. 2100, Chicago 2, Ill.
206 Connally Bldg., Atlanta 3, Ga.

WHEREVER RELIABLE, PERFORMANCE-PROVED PIPE IS NEEDED, SPECIFICATIONS CALL FOR VITRIFIED CLAY

Rantoul, Ill. (Chanute Field)	158,000 ft.
Orlando, Fla. (Air Force Base)	74,000 ft.
Morrisville, Pa. (New Steel Defense Plant)	300,000 ft.
Rapid City, S. D. (Air Base)	54,000 ft.
Bakersfield, Calif. (Air Base)	196,000 ft.
Panama City, Fla. (Municipal Expansion)	450,000 ft.
Limestone, Me. (Air Force Base)	65,000 ft.
Tucson, Ariz. (Air Base)	440,000 ft.

Vitrified
CLAY
PIPE
NEVER WEARS OUT!

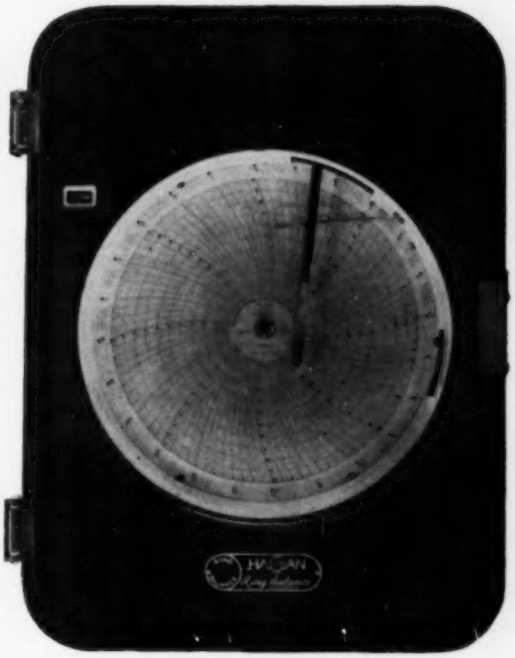
C-352-1

use dependable HAGAN

Ring Balance Flow Meters

to measure flow of

water–gas–
steam–oil–
air–other fluids



There are many reasons why you get dependable records when you use Hagan Ring Balance Flow Meters.

These include the unique ring torque resistance system which not only makes it possible to meter low flows reliably, but also provides an integral and convenient means for altering the meter capacity to any value over a 3½ to 1 range. Range changing is further simplified by a dead weight method of calibration. Other features include:

- No stuffing boxes
- Adjustable full scale range
- High sensitivity at low flow rates
- Mercury level not critical

Dependable pressure and temperature compensation (either or both) can be furnished with all Hagan Ring Balance Flow Meters.

An economical feature of all Hagan Ring Balance Meters is that maintenance costs are low. For other information on how versatile Hagan Ring Balance Flow Meters will answer your metering problems, clip the coupon, or write.

HAGAN CORPORATION

HAGAN BUILDING

PITTSBURGH 30, PA.

Ring Balance Flow and Pressure Instruments
ThrusTorq Force Measuring Devices
Boiler Combustion Control Systems
Metallurgical Furnace Control Systems

Hagan Corporation WS-4
Hagan Building
Pittsburgh 30, Pennsylvania

Please send me further information on Hagan Ring Balance Meters.

I am particularly interested in.....

.....

NAME.....

POSITION.....

COMPANY.....

STREET AND NUMBER.....

CITY..... ZONE.... STATE.....

CARLON *Plastic Pipe...*

Is Easier to Handle

Is Faster to Install

Lasts Longer

. . . **CARLON "WS"** plastic water service pipe **recommended for municipal water systems . . . sewage disposal . . . land drainage . . .** other **medium-pressure applications . . . Guaranteed against rot, rust and electrolytic corrosion . . . Will not accumulate scale or sediment . . . Impervious to chemical attack of corrosive soils and waters . . . Furnished in long lengths . . . requires fewer fittings . . . Quickly installed** without special tools . . . Can be connected with established metallic systems.

Nominal Pipe Size	O. D.	I. D.	Working Pressures P.S.I. @ 120°F	Weight Per Foot	Normal Shipping Lengths
$\frac{3}{4}$"	1.170	.824	120	.216	400' coils
1"	1.433	1.070	120	.285	300' "
1 $\frac{1}{4}$"	1.850	1.380	120	.477	300' "
1 $\frac{1}{2}$"	2.260	1.610	120	.790	250' "
2"	3.000	2.070	120	1.88	200' "
2"	2.495	2.070	75	.620	200' "
2 $\frac{1}{2}$"	2.950	2.470	75	.820	150' "
3"	3.670	3.070	75	1.280	100' "
4"	4.820	4.030	75	2.200	25' straight
6"	7.260	6.070	75	5.000	25' "

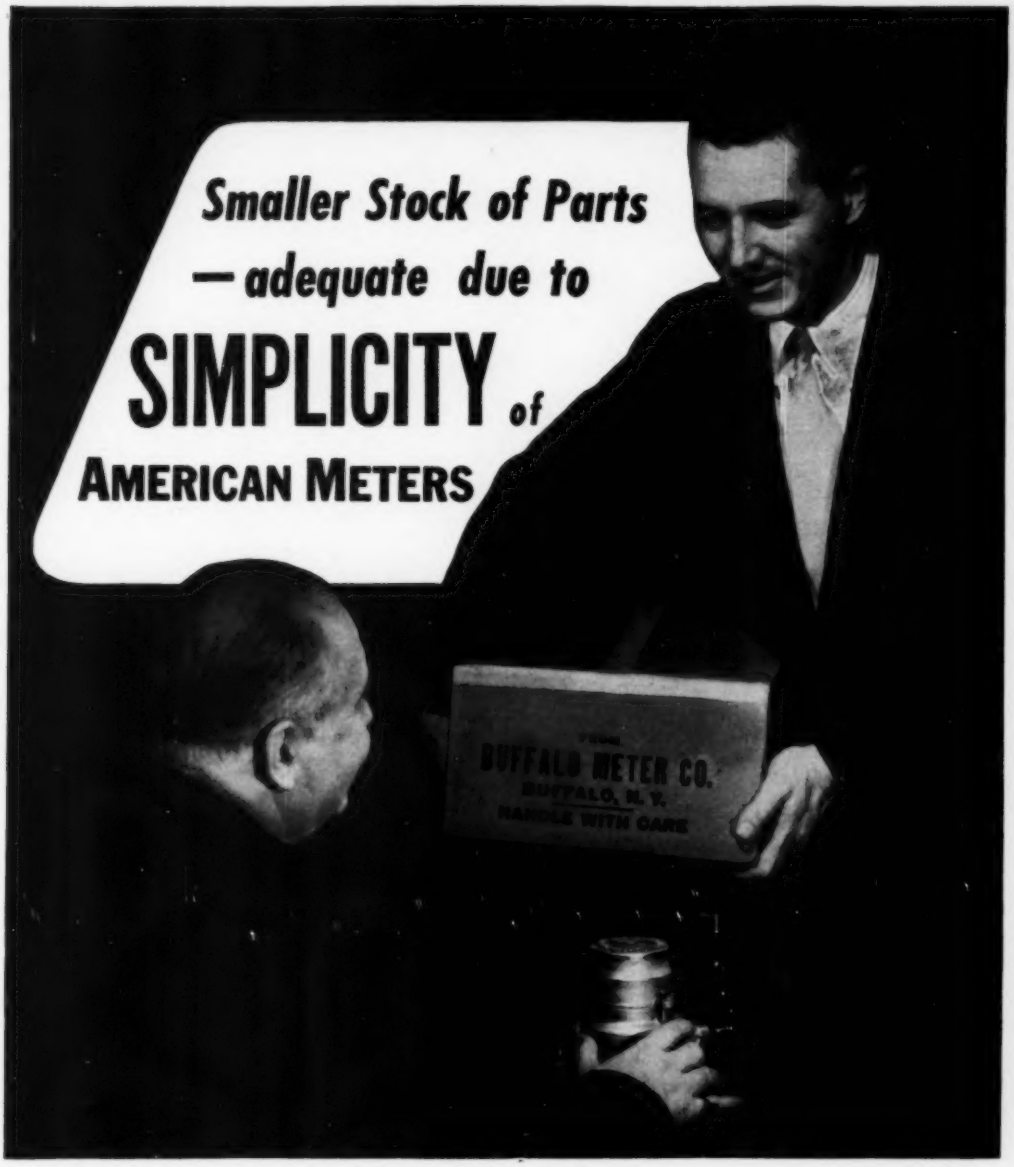
Specify the Pipe with the Stripe!

532-CP

CARLON PRODUCTS CORPORATION

IN CANADA: MICRO PLASTICS, LTD., ACTON, ONTARIO

10300 MEECH AVENUE • CLEVELAND 5, OHIO



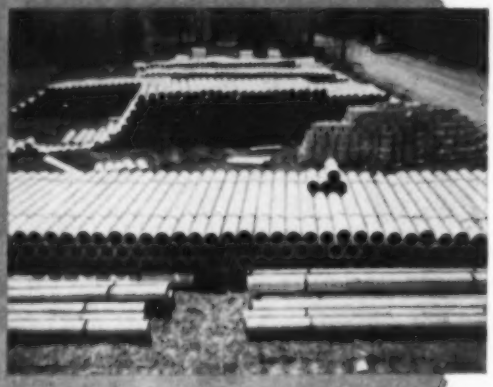
• Here in this one box are the repair parts recommended for a city placing 1,000 meters in service. Individual parts as well as complete assemblies are interchangeable, in all meters supplied during the past 30 years.

Improvements have been made in the construction of parts and in metallurgy to improve operation and increase life. But parts remain fully interchangeable to save your dollars. American Meters are still the simplest with the fewest parts.

Ask for complete data.

BUFFALO METER CO.

2909 MAIN STREET, BUFFALO 14, NEW YORK



Storage of "Century" Pipe and "Century" Simplex Couplings is shown here on site in New England preparatory to installation.

"Century" Pipe awaiting installation.

K&M ASBESTOS ROPE

For yarning bell and spigot joints will not promote the breeding of bacteria. Write for details.

WRITE FOR FREE BOOKLET, "Mains without Maintenance". Gives valuable data, specifications, and reference material for anyone interested in water main pipes.

"CENTURY"

ASBESTOS-CEMENT PIPE gives a New England town 19 miles of trouble-free water mains

Thus, another community is added to the growing and already large number of places in every State where this modern water main has been adopted.

Right from the start this modern water system provides economical operation by the relatively low cost of installation and reduced carrying charges plus the advantages inherent in the pipe itself.

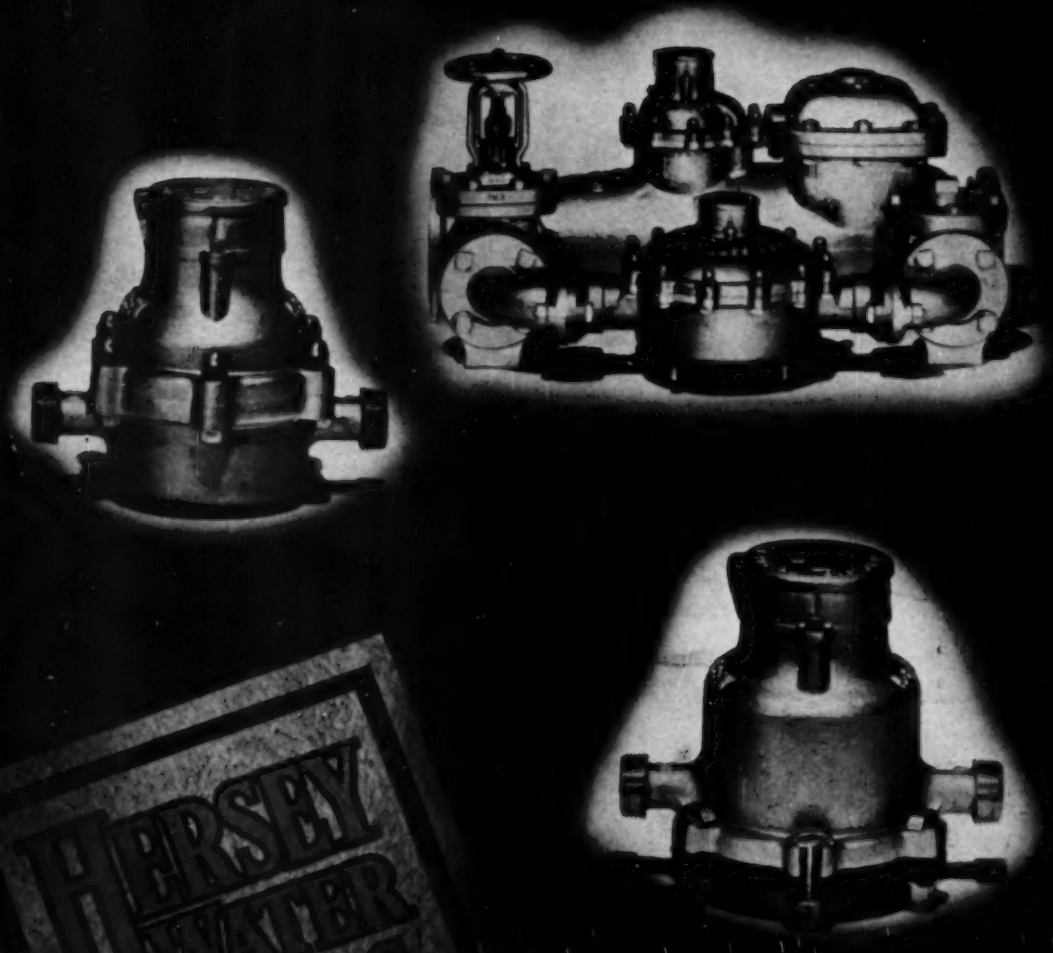
Made of two practically indestructible materials, asbestos fiber and portland cement, "Century" Pipe is strong and durable. It is highly resistant to external corrosion and internal corrosion (tuberculation) cannot take place due to its non-metallic composition. The permanently smooth inner surface guarantees continuous flow and minimum pumping costs

It will pay you to investigate the many cost saving features of "Century" Asbestos-Cement Pipe.

Nature made Asbestos . . .
Keasbey & Mattison has made it serve mankind since 1873

KEASBEY & MATTISON
COMPANY • AMBLER • PENNSYLVANIA

"See us at Booths No. 13 and 14, American Water Works Association Convention, Kansas City, Missouri, May 4-9, 1952"



From the giant **DETECTOR METER** to the small domestic Meter, there is a Hersey Water Meter made for every water works need.

← THIS BOOK WILL GIVE YOU COMPLETE DESCRIPTIONS OF ALL

Hersey Water Meters

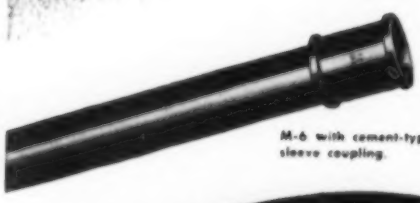
Available at your nearest Branch Office

HERSEY MANUFACTURING COMPANY

SOUTH BOSTON, MASS.

BRANCH OFFICES: NEW YORK — PORTLAND, ORE. — PHILADELPHIA — ATLANTA
DALLAS — CHICAGO — SAN FRANCISCO — LOS ANGELES

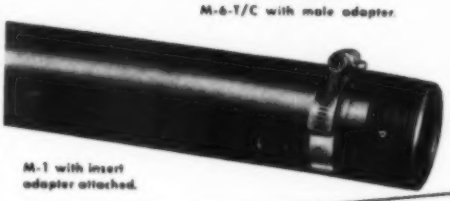
Yardley PLASTIC PIPE for water or waste disposal systems



M-6 with cement-type sleeve coupling.

M-2 flexible type.

M-6-T/C with male adapter.



M-1 with insert adapter attached.

Whatever the need . . . for cold water or corrosive liquids, suction or discharge . . . there's a Yardley Plastic Pipe for the job.

Made from rigid or flexible light-weight material. Acid and alkali resistant. Won't rot, rust or corrode. Produced in a full range of pipe and tubing sizes, ⅛" through 6". Complete line of standard fittings and adapters. Easier to install, more economical to handle.

Send for chemical resistance charts.

YARDLEY PLASTICS CO.
142 Parsons Ave. • ADams 9315
Columbus 15, Ohio

YARDLEY M-1 and M-2 FLEXIBLE PIPE SPECIFICATIONS

PIPE SIZE	NOMINAL O. D.	NOMINAL I. D.	CALCULATED B. P. P. S. I.	APPROXIMATE WT. PER FT.	NORMAL SHIPPING LENGTHS
⅛"	.820	.620	340#	.092	400' Coils
¾"	1.080	.840	350#	.141	400' Coils
1"	1.340	1.100	200#	.179	300' Coils
1¼"	1.660	1.360	200#	.263	300' Coils
1½"	1.900	1.610	200#	.357	250' Coils
2"	2.375	2.067	170#	.434	200' Coils
3"	3.500	3.068	165#	.899	100' Coils
4"	4.500	4.026	150#	1.220	25' Straight
6"	6.675	6.065	115#	2.400	25' Straight

YARDLEY M-6 AND M-6-T/C RIGID PIPE SPECIFICATIONS

PIPE SIZE	APPROXIMATE WT. PER FT.	NOMINAL I. D.	NOMINAL O. D.	CALCULATED BURST PRESSURE P.S.I. AT 80° F.
⅛"	.053	.476	.600	700
¾"	.080	.715	.855	625
1"	.138	.970	1.140	550
1¼"	.20	1.230	1.420	525
1½"	.32	1.510	1.730	490
2"	.45	2.00	2.250	400
3"	.553	3.000	3.250	375
4"	.880	4.000	4.300	342
6"	1.940	6.000	6.440	335

M-6 and M-6-T/C recommended for working pressures up to 20% of calculated bursting pressures where temperatures do not exceed 125°. For M-1 and M-2 working pressures, use 60% of calculated burst.

Worthington-Gamon

WATCH DOG WATER METERS

The meter used by thousands of municipalities in the U. S. and abroad.

SURE TO MEET YOUR SPECIFICATIONS FOR ACCURACY, LOW MAINTENANCE, LONG LIFE

Before you invest in water meters, get acquainted with the design and performance advantages which make Worthington-Gamon Watch Dog Water Meters first choice of so many municipalities and private water companies in the United States.

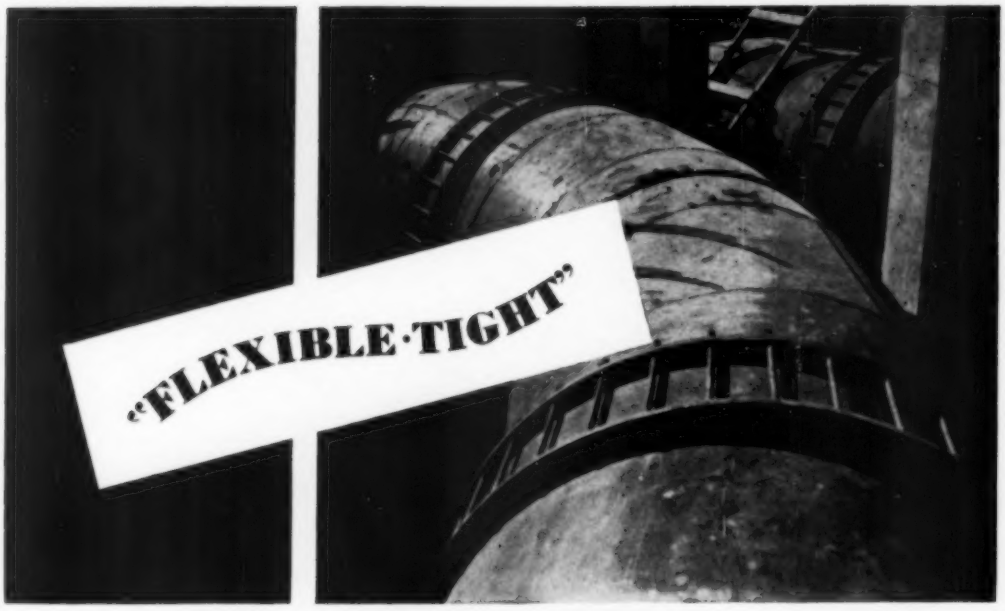
WATCH DOG WATER METERS

"Watch Dog" models . . . made in standard capacities from 20 gpm up; frost-proof and split case in household sizes. Disc type, Turbine type or Compound type. Write for Bulletin.

WORTHINGTON-GAMON METER DIVISION

Worthington Corporation

296 South Street, Newark 5, New Jersey



Joined for a lifetime...

These twin 67" air mains are a part of Sanitary District Sewage Works, in Chicago. Joined with Dresser Couplings to provide complete year-round dependability, they supply tremendous volumes of compressed air for Chicago aeration tanks. Expensive leaks could not be tolerated.

A fraction of a pound saved in air pressure would result in dollars saved in electric power costs. Dressers were selected for the job to assure that saving.

Dressers provide complete dependability because they stay airtight despite pipe movements common to all lines through the seasons. Specially compounded rubber gaskets in Dresser Couplings take up expansion-contraction stresses, vibration, earth movements, and stress from settling foundations.

And Dressers are factory built and tested . . . ready to install when you get them.

Installation is simple. Average time is 2 man-minutes per bolt, using only a wrench. You save time and labor costs, and eliminate the need for expensive repairs and maintenance, because Dressers stay "Flexible-Tight". In numerous installations they have been in service 50 years and more.

Write today for more information about Dresser applications on water, sewage, and industrial waste projects.

Dresser-Coupled air distribution lines to aeration tanks at the West Side Sewage Treatment Plant, in Chicago. Here again, sanitary engineers selected Dressers to assure airtight pipe joints through the entire distribution system. Simple, economical construction that can be depended on for years of trouble-free service.

DRESSER

"FLEXIBLE-TIGHT"

COUPLINGS

Dresser Manufacturing Division, 59 Fisher Ave., Bradford, Pa. (One of the Dresser Industries). Warehouses: 1121 Rothwell St., Houston, Texas; 101 S. Bayshore Highway, South San Francisco, California. Sales Offices: New York, Philadelphia, Chicago, Houston, South San Francisco. In Canada: 629 Adelaide St., W., Toronto, Ont.

Dependable Water Service in Montgomery County

Montgomery County, Ohio, recently installed this 1,000,000-gallon Horton tank to provide the beautiful suburban area south of Dayton with more dependable water service.

As many communities have discovered, elevated storage results in three important advantages . . . increased water pressure . . . decreased pressure variations . . . and reduced pumping costs. Combine these advantages with modern appearance and it's understandable why Horton elevated tanks serve so many areas throughout the country.

The radial-cone bottom design of the Montgomery County tank was developed especially for large capacity tanks. It allows elevated tanks to be built in capacities up to 3,000,000 gallons with a range of only 25, 30, or 35 ft. between the upper and lower water levels.

Horton water tanks are of welded steel construction for lower maintenance costs and longer life. Smooth surfaces are easier to paint and the protective coating is more effective.

Write our nearest office for complete information. There is no obligation on your part.

HORTON

WELDED STEEL

STORAGE TANKS

CHICAGO BRIDGE & IRON COMPANY

Plants in Birmingham, Chicago, Salt Lake City, and Greenville, Pa.

Atlanta 3	2181 Healey Building	Los Angeles 17	1555 General Petroleum Building
Birmingham 1	1586 North Fiftieth Street	New York 6	3390-165 Broadway Building
Boston 10	1040-201 Devonshire Street	Philadelphia 3	1644-1700 Walnut Street Building
Chicago 4	2198 McCormick Building	San Francisco 4	1583-200 Bush Street
Cleveland 15	2262 Guildhall Building	Seattle 1	1350 Henry Building
Detroit 26	1551 Lafayette Building	Tulsa 3	1646 Hunt Building
Houston 2	2115 C & I Life Building	Washington 6, D.C.	1109 Cafritz Building

GOOD NEIGHBOR POLICY AT WORK

San Francisco can justly be proud of its recently completed North Point Sludge Treatment Plant. Adjacent to a residential section, the "good neighbor" policy was applied here. Every means has been taken to make this campus-like plant a "good neighbor" . . .

For example, ten P.F.T. Floating Cover Digesters, each 100′ dia., served by eight No. 1500 P.F.T. sludge gas fired Digester Heaters and Heat Exchangers, provide safe, efficient Controlled Digestion. This includes volatile acids and ammonia nitrogen control. P.F.T. Pressure Gauges and a full complement of P.F.T. Gas Safety Equipment insure plant safety. Also significant is the 55′6″ dia. P.F.T. spirally guided gas control holder lift. Primary settling tanks are housed in "neighborly" buildings.

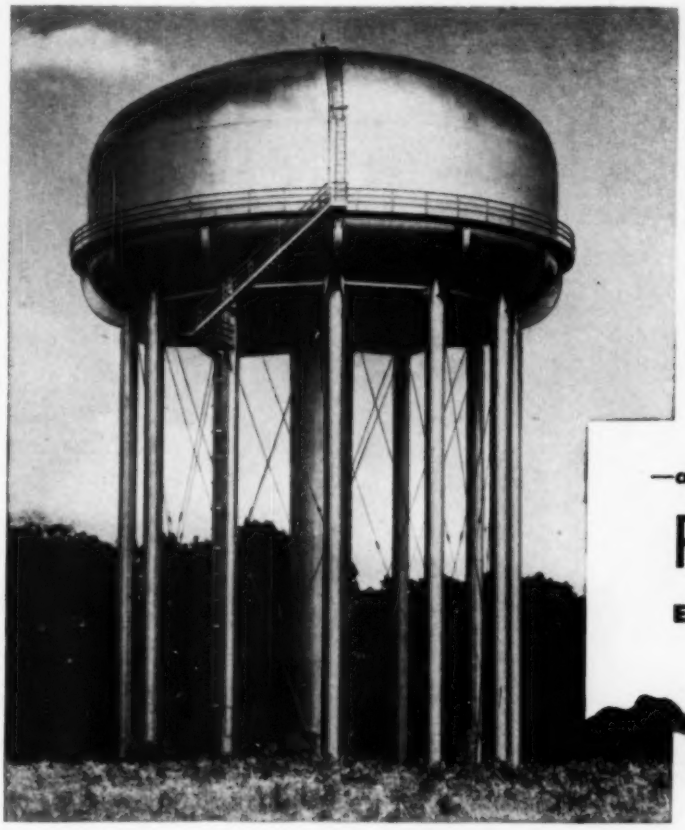
This sludge processing plant with a 2,451,000 cu. ft. capacity handles sludge from the North Point Sewage Treatment Plant over six miles distant, as well as sludge from the Southeast Treatment Works close by — serving a total population of 1,169,000. North Point's sludge combined with digested sludge from the Richmond-Sunset Treatment Plant, is vacuum filtered and heat dried for use as fertilizer. The Engineering Offices of Clyde C. Kennedy, San Francisco, were consulting engineers.

P.F.T. **PACIFIC FLUSH TANK CO.**

Waste Treatment Equipment Exclusively Since 1893

4241 RAVENSWOOD AVE. CHICAGO 13, ILLINOIS

NEW YORK • LOS ANGELES • SAN FRANCISCO • CHARLOTTE, N. C. • JACKSONVILLE • DENVER



for

Cincinnati, Ohio

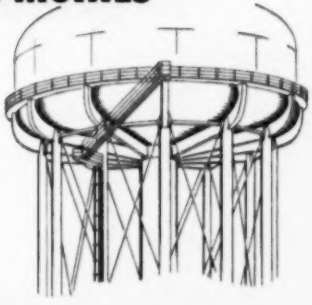
—a million gallon

RADIAL CONE

ELEVATED STEEL TANK

by PITTSBURGH • DES MOINES

The *Radial Cone* design is particularly applicable for elevated tanks of medium to large capacity where *low head range* is an important consideration. • Write for a discussion of the Pittsburgh-Des Moines elevated tank type best meeting *your* requirements.



PITTSBURGH • DES MOINES STEEL CO.

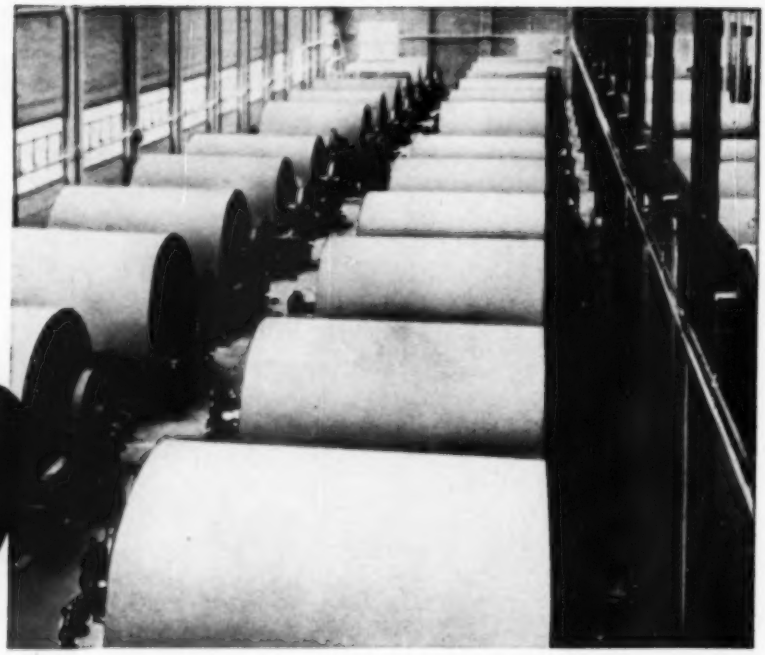
Plants at PITTSBURGH, DES MOINES and SANTA CLARA

Sales Offices at:

PITTSBURGH (25)	3418 Neville Island	DES MOINES (8)	919 Tuttle Street
NEWARK (2)	218 Industrial Office Bldg.	DALLAS (1)	1223 Praetorian Building
CHICAGO (1)	1272 First National Bank Bldg.	SEATTLE	526 Lane Street
LOS ANGELES (48)	6399 Wilshire Blvd.	SANTA CLARA, CAL.	675 Alviso Road

See General American for

CREATIVE FILTER ENGINEERING



Designed to do your job best!

66 Conkey Sludge Filters now installed in one plant of Chicago Sanitary District

The West-Southwest Treatment Works of the Chicago Sanitary District is the largest sewage treatment plant in the world. Here, the huge volume of industrial and residential waste from the heavily populated metropolitan area has presented sewage engineers with an unparalleled challenge. Progressively, the Chicago Sanitary District has met that challenge. Starting twenty years ago with installations of continuous vacuum filters for activated sludge, Sanitary District engineers have developed the most exacting specifications and rigid requirements for filter designs and performance . . . culminating in the installation of 66 Conkey Rotary Drum Vacuum Filters for this largest single installation in the sewage field.

These Conkey units incorporate:

Polystyrene plastic cloth backing drainage plates for long cloth life and low maintenance.

Flotating cake discharge scraper.

Protective coatings for filter components.

—and other superior design and construction features.

For equivalent Conkey design and fabrication for your filter installation, write General American. Ask for bulletin No. 100 or for a consultation with one of our engineers.

Other General American Equipment:
Turbo-Mixers, Evaporators, Dewaterers, Dryers, Towers, Tanks, Bins, Pressure Vessels

OFFICES IN ALL PRINCIPAL CITIES

Process Equipment Division
GENERAL AMERICAN
Transportation Corporation
Sales Office: 10 East 49th St., New York 17, N. Y.
General Offices: 135 S. La Salle St., Chicago 90, Ill.
In Canada: Canadian Locomotive Co., Ltd., Kingston, Ont.

Information courtesy Cleveland Dept. of Public Works—Mr. G. E. Flower, Commissioner of Sewage Disposal.

Cleveland's Easterly sewage plant uses ALOXITE diffusers

The well cared for park-like area you see from Lake Shore Blvd. in Cleveland, opposite East 140th St., is actually part of this large Easterly Sewage Treatment Plant. Looking along the lake shore here, the aeration tanks, galleries, etc., can be seen to the left.

This modern plant uses the air diffusion process, employing ALOXITE aluminum oxide diffusers. This type of aeration gives the high degree of treatment — at low cost — essential to a densely populated area. It affords the necessary protection for Cleveland's water supply and bathing beaches. And it provides odor control which, of course, is vitally important.

The ALOXITE porous plates in this plant have been in service for a number of years, and have proved most satisfactory.

YOU'LL WANT OUR POPULAR BOOKLET. This new 56-page booklet covers different filtration and diffusion designs, gives pointers on material specifications, and outlines how to install and operate porous media in various units. It's complete with photos, charts, etc. Write for your free copy today.

Porous filter media and diffusers by

CARBORUNDUM

Trade Mark

Dept. M-42, Refractories Div. The Carborundum Company Perth Amboy, N. J.

"Carborundum" and "Aloxite" are registered trademarks which indicate manufacture by The Carborundum Company.

LEOPOLD
Glazed Fire Clay
TILE FILTER BOTTOMS

Successfully serving over 200 PLANTS with a daily capacity of over THREE-QUARTER BILLION GALLONS

Check THESE **LEOPOLD** FEATURES:

Permanent · No corrosion or tuberculation · Economical · Equal distribution · Uniform filtration · Low loss of head · No large size gravel required · Proved superiority · No metal in contact with water!

PARTIAL LIST OF MUNICIPAL INSTALLATIONS

Tuscaloosa, Ala.
Phoenix, Ariz.
Little Rock, Ark.
Trinidad, Col.
Washington, D.C.
Fort Lauderdale, Fla.
Evanston, Ill.
Indianapolis, Ind.
Council Bluffs, Iowa
Kansas City, Kansas
Topeka, Kansas
Owensboro, Ky.
Shreveport, La.
Monroe, Mich.
Columbia, Mississippi
North Kansas City, Mo.
Billings, Montana
Lincoln, Neb.
Lima, Ohio
Bartlesville, Okla.
Eugene, Oregon
Philadelphia, Pa.
Allentown, Pa.
Memphis, Tenn.
Fort Worth, Texas
Port Arthur, Texas
Wichita Falls, Texas
Norfolk, Va.
Wheeling, W. Va.
Menasha, Wis.
Worland, Wyo.
Passaic Valley Water Commission, Little Falls, N.J.

F. B. LEOPOLD CO., INC.
2413 W. CARSON ST., PITTSBURGH 4, PA.
COMPLETE WATER PURIFICATION and SEWAGE PLANT EQUIPMENT
DRY CHEMICAL FEEDERS · FILTER OPERATING TABLES · MIXING EQUIPMENT

Chemicals you live by

WHAT'S NOT SAID IN M-31..

As in '51—the amended January M-31 for '52 states that municipalities shall be assured the same amount of chlorine they received in 1950 from the same supplier.

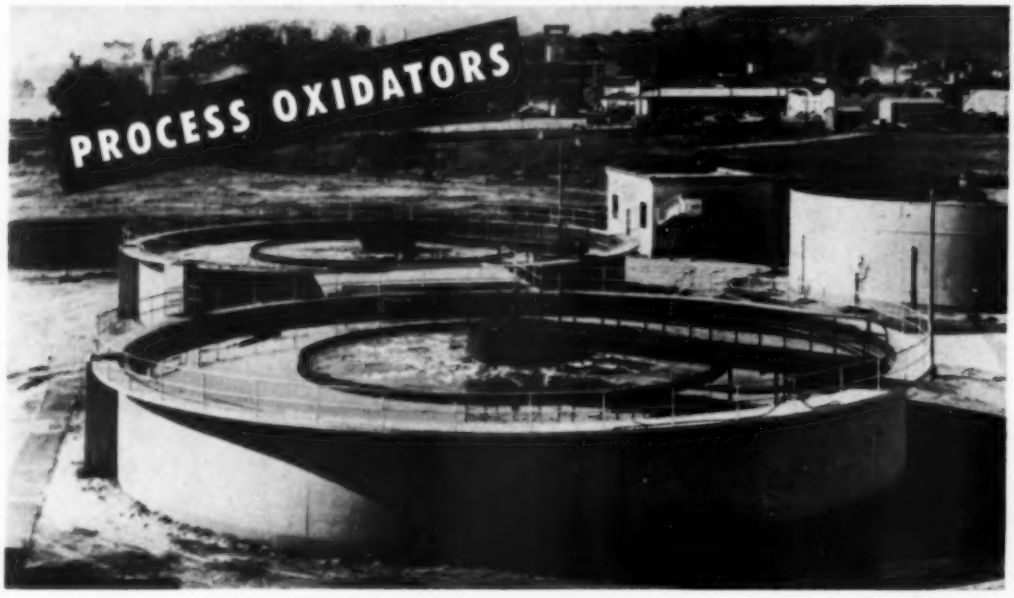
What's not said is that chlorine manufacturers will have the same number of containers for shipping the chlorine. We are delighted to be able to supply our customers—but we must ask that you get the empty containers back promptly.

We cannot fill your order unless you return our empty containers for re-filling.

CHLORINE DEPARTMENT

DIAMOND ALKALI COMPANY...CLEVELAND 14, OHIO

DIAMOND ALKALI CHEMICALS



The Picture that Speaks for Itself!

THIS is a graphic illustration of the Process Oxidator* at work. Shown are two single stage, 80 ft. dia. Oxidators at the new Santa Barbara, California Sewage Treatment Plant designed for a population of 60,000 by Koebig & Koebig, Consulting Engineers.

The Oxidators combine aeration, coagulation and sedimentation in a single circular tank giving the results of intermediate treatment at practically the cost of primary treatment. Note the excellent aeration in the center well and the absence of scum in the sedimentation compartment.

What the picture can't tell is that the installation of Process Oxidators results in improved clarification, greater reduction of biochemical oxygen demand, higher grease removals, plus the Oxidators' ability to maintain the sewage in a fresh condition thus eliminating odor problem. These factors have combined to give the City of Santa Barbara a sewage treatment plant at a lower initial cost with higher efficiency of operation and reduced maintenance expenditure.

If you are planning a new sewage disposal installation or the improvement of your present plant, be sure to investigate this new leader in economy and efficiency. Simply write to any of the addresses listed below for complete information or ask for one of our specialized engineers to consult with you.

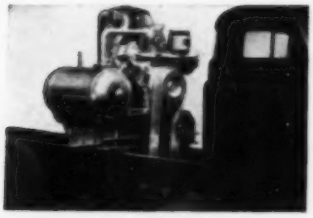
*Patented and Patents Pending.

PROCESS ENGINEERS INCORPORATED

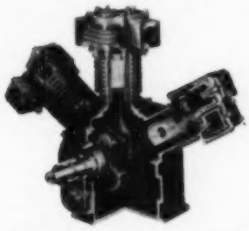
212 SUTTER STREET
SAN FRANCISCO 8, CALIF.

6381 HOLLYWOOD BLVD.
LOS ANGELES 28, CALIF.

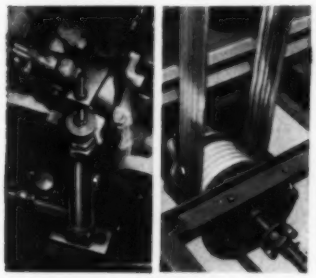
EASTERN AND MIDDLE WESTERN REPRESENTATIVE:
PACIFIC FLUSH-TANK COMPANY • 4241 RAVENSWOOD AVE., CHICAGO 13, ILL.



More Capacity: 125 cfm at 100 psi. Runs 2 heavy pavement breakers at full efficiency, with truck engine at only 1750 rpm.



Smooth Operation: No vibration under full load with this perfectly balanced 2-stage W-type compressor unit.



Simplest Automatic Control: Regulates engine speed to air demands without complicated linkage. Positive in action.

Comco Power Take-Off: No gears. Only 4 moving parts. Clutch controlled from cab.

Utilities that never before used truck-powered compressors are installing the JAEGER TRAVEL-AIR

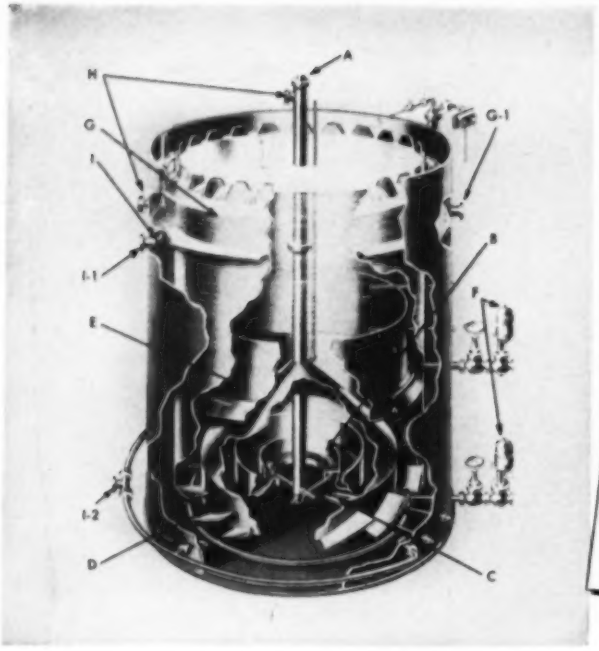
More air, no vibration, simple automatic control of engine speed—plus the advantages of power take-off

By taking power from your truck engine, which otherwise stands idle 7 hours out of 8, you save $950 to $1,000 in cost, 50% of the maintenance and all the extra weight and bulk of a separate engine and trailer mounting. Also saves waiting for engine to warm up at every job.

By using the air-cooled Jaeger 125 cfm compressor unit (largest selling compressor in the construction field) you get 20 cfm more air to run your tools at full efficiency.

Easy to mount on 1½ and 2 ton Chevrolet, Dodge, Ford, GMC or International trucks of long wheelbase current model. Get our Catalog TC-1, giving full information.

THE JAEGER MACHINE CO.,
680 Dublin Avenue, Columbus 16, Ohio
PUMPS • MIXERS • PAVING MACHINERY
SALES AND SERVICE IN 153 CITIES OF U.S. AND CANADA



Vortex mixing eliminates need for submerged moving parts in the Worthington Cold Process Slurry Type Precipitation Water Softener and Coagulator.

REACTION TANK of Worthington Slurry Type Softener (Slurry bed eliminated for clarity). (A) Raw water influent line. (B) Vortexor for optimum slurry production. (C) Chemical Applicators. (D) Slurry bed rotator. (E) Symmetrical Slurry concentrator. (F) Proportionate sludge removal. (G) Collector trough for treated water. (G-1) Treated water effluent. (H) Complementary recirculation. (I) Filter wash water compartment. (I-1) Filter wash water suction. (I-2) Filter wash water return.

This slurry bed stays put!

. . . and troublesome variables are out

These Features Give You The Uniformity You Want

WORTHINGTON SLURRY TYPE PRECIPITATING WATER SOFTENER AND COAGULATOR gives consistent, uniformly softened water

If it's clear, uniformly softened water you want, this unique Worthington Water Softener is just what you need. Concentrated quick mixing and rapid recirculation of applied chemicals and raw water, *achieved by hydraulic energy instead of submerged mechanical moving parts*, is an important, progressive development in the water treatment field.

New Bulletin W-212-B5 gives you 16 pages of vital facts about this unique cold process water softening method. Write for your free copy today.

REMEMBER . . .

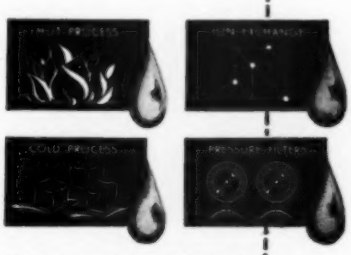
Worthington engineers *all four* water conditioning processes, therefore, can give you unbiased recommendations on which process is right for you . . . further proof that *there's more worth in Worthington. Worthington Pump and Machinery Corporation, Water Treating Division, Harrison, N. J.*

JO-1

WORTHINGTON

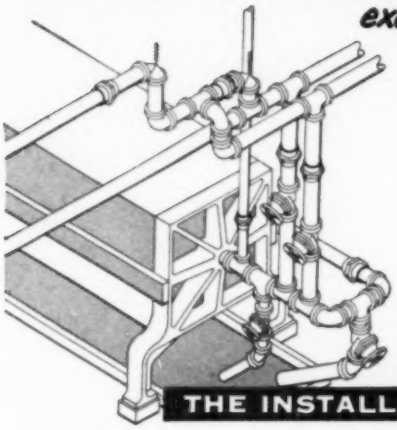
WATER CONDITIONING

Worthington Makes More of the Equipment for All Types of Water Conditioning Systems



Do Your Valves Last This Long?

...on Semi-Solids, for example



THE INSTALLATION

Crane Packless Diaphragm Valves handling liquid clay to filter presses. Onondaga Pottery Co., Syracuse.

VALVE SERVICE RATINGS

SUITABILITY:	Fluid can't get into working parts
MAINTENANCE COST:	None yet – Big saving indicated
CORROSION-RESISTANCE:	Excellent
SERVICE LIFE:	5 times longer already – no sign of wear
OPERATING RESULTS:	No interruptions – Easier operation – Lower cost
PRICE:	Good
AVAILABILITY:	Stock item – Crane

THE HISTORY

Plug cocks were used in this service before replacing with Crane Diaphragm Valves. But the cocks lasted no more than 2 to 8 weeks. They quickly cut out at the plug and body, damaged by the gritty particles and highly erosive effects of liquid clay at 140 psi. pressure.

After 11 months' uninterrupted service, Crane Diaphragm Valves showed no significant wear or damage resulting from normal operating conditions. They sharply reduced maintenance and replacement costs over plug cocks, and were approved as standard equipment on filter press piping.

THE VALVE

In Crane Iron Body Packless Diaphragm Valves, the Neoprene diaphragm acts as bonnet seal only; is not subject to crushing and rapid wear. Separate disc with Neoprene insert shuts off flow even should diaphragm fail. Choice of fully Neoprene lined or unlined valves. Highly recommended for many common and corrosive services; sludges, slurries, etc. See your Crane Catalog or Crane Representative.

The Complete Crane Line Meets All Valve Needs. That's Why

More Crane Valves Are Used Than Any Other Make!

CRANE VALVES

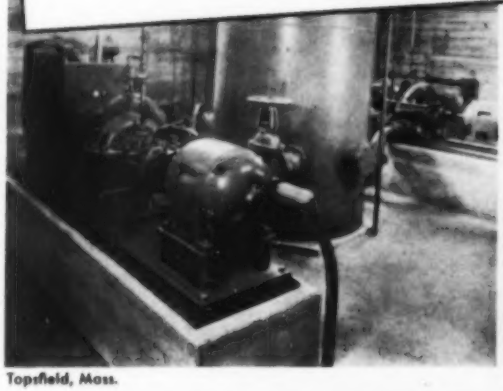
CRANE CO., *General Offices:* 836 S. Michigan Ave., Chicago 5, Illinois

Branches and Wholesalers Serving All Industrial Areas

VALVES • FITTINGS • PIPE • PLUMBING • HEATING

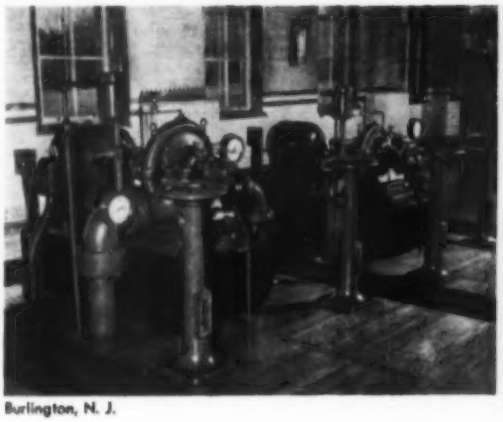
NO TIME OFF...

for these public servants

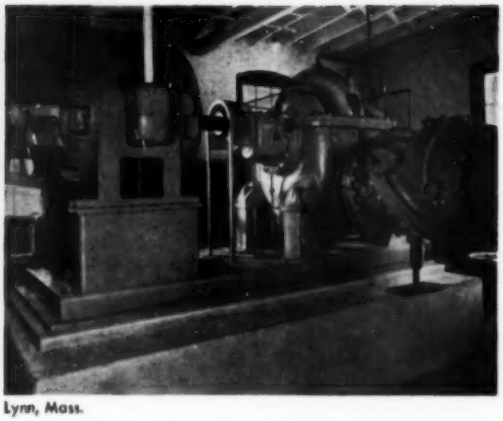


Topsfield, Mass.

Miami Beach, Fla.



Burlington, N. J.



Lynn, Mass.

Here are four typical De Laval centrifugal pump installations that will keep giving efficient, continuous service for years to come. In fact, since the turn of the century De Laval water works pumps have been serving both big cities and small towns throughout the nation. These pumps are available in capacities ranging from less than one mgd to more than 100 mgd.

LOOK TO DE LAVAL FOR DEPENDABILITY

DE LAVAL *Centrifugal Pumps*

DE LAVAL STEAM TURBINE CO., TRENTON 2, NEW JERSEY

DL 189

A few of the Darling gate valves now serving a recently built pumping station in the Southwest. Included are 20" O. S. & Y. valves as well as 30" and 36" sizes with beveled gears and gear cases. All employ Darling's unique revolving double disc feature and comply with A.W.W.A. specifications.

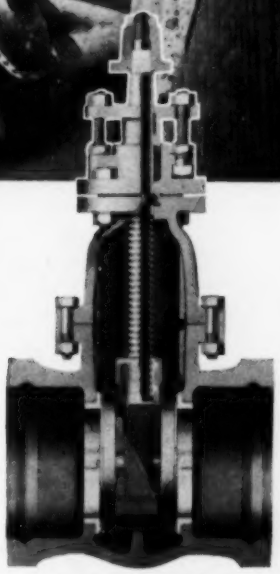
Planned Economy...

with Darling fully revolving double disc gate valves

IN water and sewage plants, there's a sure-fire way to plan for years and years of lowest-cost gate valve performance. That's the experience in plant after plant where Darling fully revolving double disc, parallel seat gate valves are on the job.

These valves come closer to being trouble-*proof* than any you've ever run across. In the event of valve body distortion, the unique wedging feature *automatically* adjusts discs to seats for drop-tight closure. And to cinch prolonged, low-maintenance service, wear is *uniformly* distributed because the fully revolving discs take a *different seating position* at every closure!

It adds up to smooth, reliable operation, and greater service life with minimum attention. But why not get *all* the facts on how Darling valve features can work to your advantage?



Note rugged simplicity of this unique Darling principle—just four sturdy working parts . . . two plain interchangeable no-pocket discs and two husky wedges. Assembly and maintenance is extremely easy and foolproof.

SEND FOR BULLETIN No. 5002

Darling's latest bulletin is full of helpful information and describes Darling valves for every normal or unusual service . . . yours for the asking.

DARLING VALVE & MANUFACTURING CO.

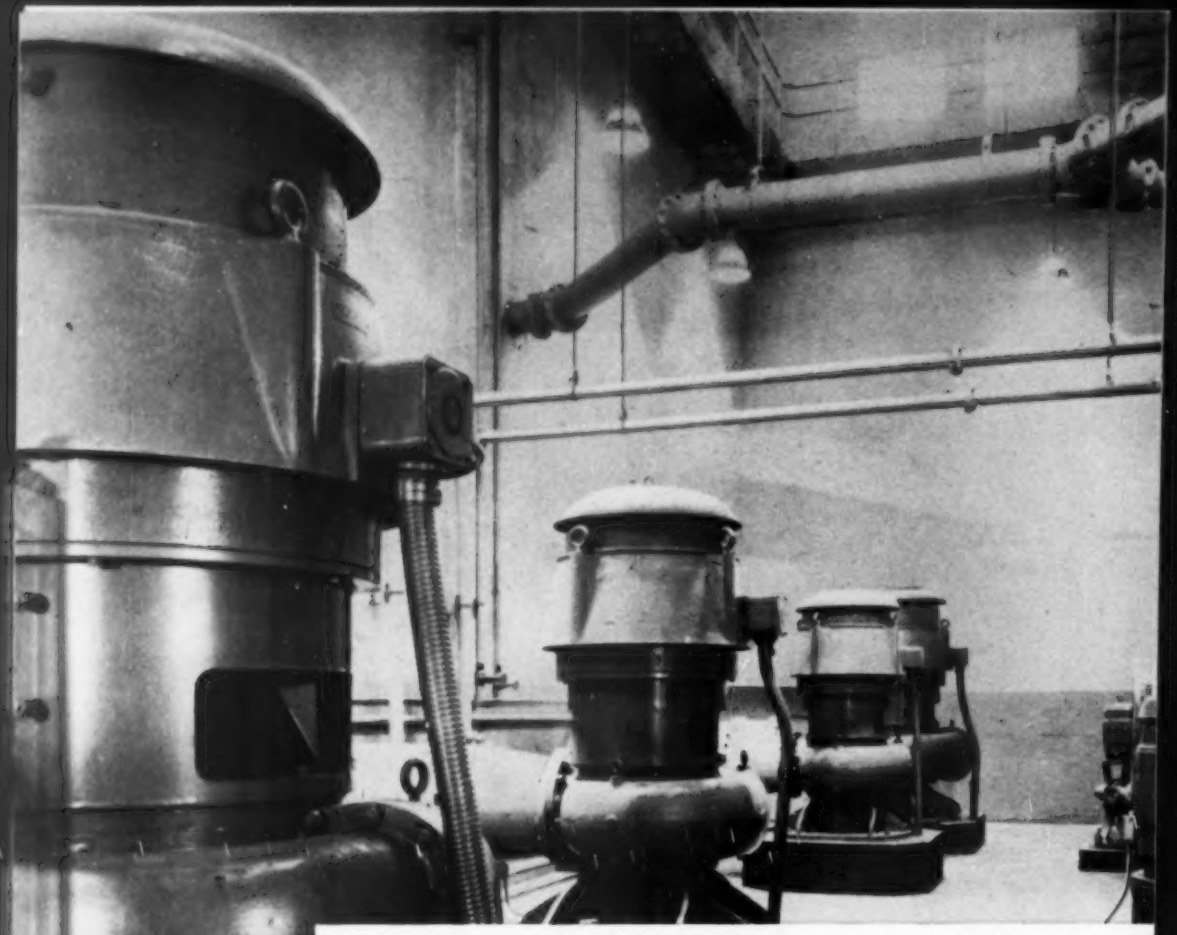
Williamsport 11, Pa.

Manufactured in Canada by The Canada Valve & Hydrant Co., Ltd., Brantford 7, Ont.

DARLING VALVES FOR PLUS VALUES, JOB-PROVED AGAIN AND AGAIN

DARLING

VALVES



Keep This Angle in Mind

. . . that when you want to move big volumes of sewage or storm water *economically*, your best bet is Fairbanks-Morse *Angle*flow Pumps. Designed for maximum plant efficiencies where large quantities must be pumped against moderate heads, these dependable pumps give you a new high in service . . . a new low in operating and maintenance costs. Wide, unobstructed passages through impeller and volute make them especially suitable for handling debris-filled water. Sizes range from 8 to 54 inches . . . capacities up to 80,000 g.p.m. For complete information see your local Fairbanks-Morse Branch or write Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.

FAIRBANKS-MORSE,

a name worth remembering

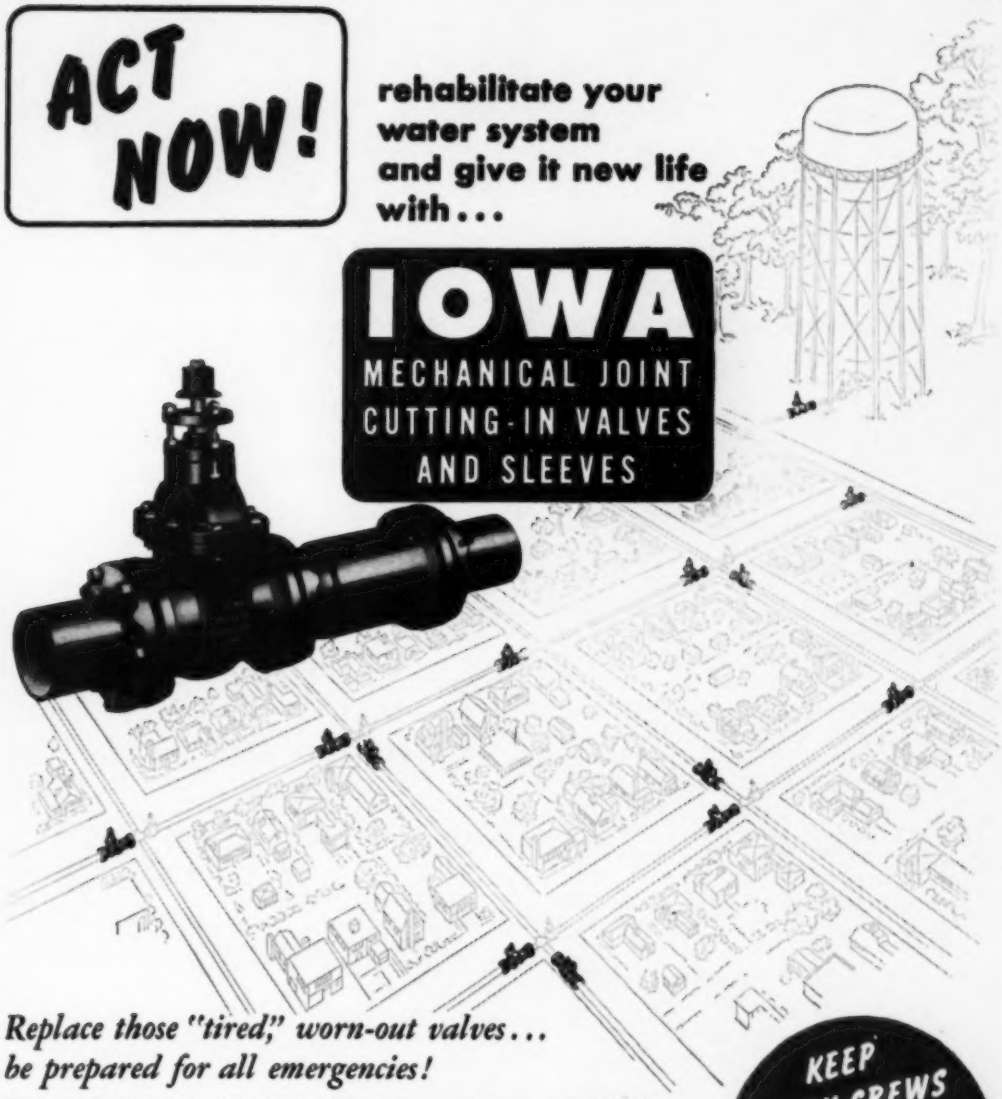
PUMPS · DIESEL LOCOMOTIVES AND ENGINES · ELECTRICAL MACHINERY · SCALES
HOME WATER SERVICE EQUIPMENT · RAIL CARS · FARM MACHINERY · MAGNETOS

ACT NOW!

rehabilitate your water system and give it new life with . . .

IOWA

MECHANICAL JOINT CUTTING-IN VALVES AND SLEEVES



Replace those "tired," worn-out valves . . . be prepared for all emergencies!

Now, more than ever, it's vital to keep your customers supplied with water and fire protection at all times . . . Replace worn-out valves and add needed valves with IOWA Mechanical Joint Cutting-In Valves and Sleeves . . . It's the fastest, simplest and most economical method of cutting gate valves into existing water lines . . . Furnished complete with joint accessories . . . No lead, no jute, no caulking . . . Just a ratchet wrench . . . Ideal as auxiliary valves for fire hydrants . . . Simplifies hydrant inspection and maintenance . . . Act now before it's too late . . . Write today for descriptive literature!

KEEP WORK CREWS BUSY ON JOBS LIKE THIS . . . IT PAYS!

IOWA VALVE COMPANY

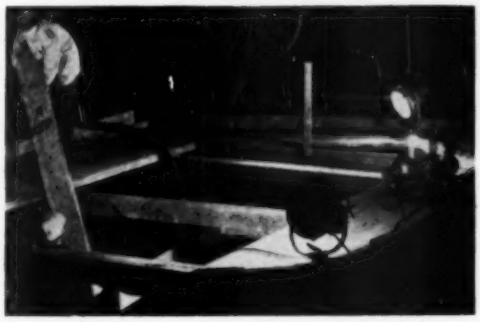
201-299 N. Talman Ave., Chicago 80, Ill. • *A Subsidiary of James B. Clow & Sons*

Three HOMELITE UNITS

that Can Cut Your Costs This Year

Homelite Carryable Pumps. In less time . . . and with less labor . . . a Homelite Gasoline Engine Driven Pump will take care of your dewatering jobs. No transportation problems. No trouble getting it on the job. One man can carry it . . . put it in operation any place quickly and easily. Handles up to 15,000 gallons per hour. Fast self-priming. Keeps seepage at strainer level automatically. 28 ft. suction lift. Non-clogging. Really dependable at all times.

Homelite Carryable Generators. Night work used to be slow work . . . and expensive work . . . but not any more. With a lightweight, carryable Homelite Gasoline Engine Driven Generator you can have, in no time and with no trouble, all the brilliant floodlights you need to speed work and cut costs in emergency night repairs. What's more, using your Homelite Generator to operate new, efficient electric tools pays off plenty in important savings in time and labor at all times, night or day.



Homelite One Man Chain Saws. For clearing storm damage or new construction sites, nothing approaches the efficiency and man-hour savings offered by the new Homelite Gasoline Engine Driven Chain Saws. Only 27 pounds, complete with 4 horsepower engine, will cut wood easier, faster, and with less trouble or maintenance than any other saw. One man can handle it easily. In fact, with the Homelite Saw one man can do more cutting in fewer hours than you would ever expect.

Send today for complete information on all Homelite Carryable Cost Cutting Units

PERFORMANCE · DEPENDABILITY · SERVICE

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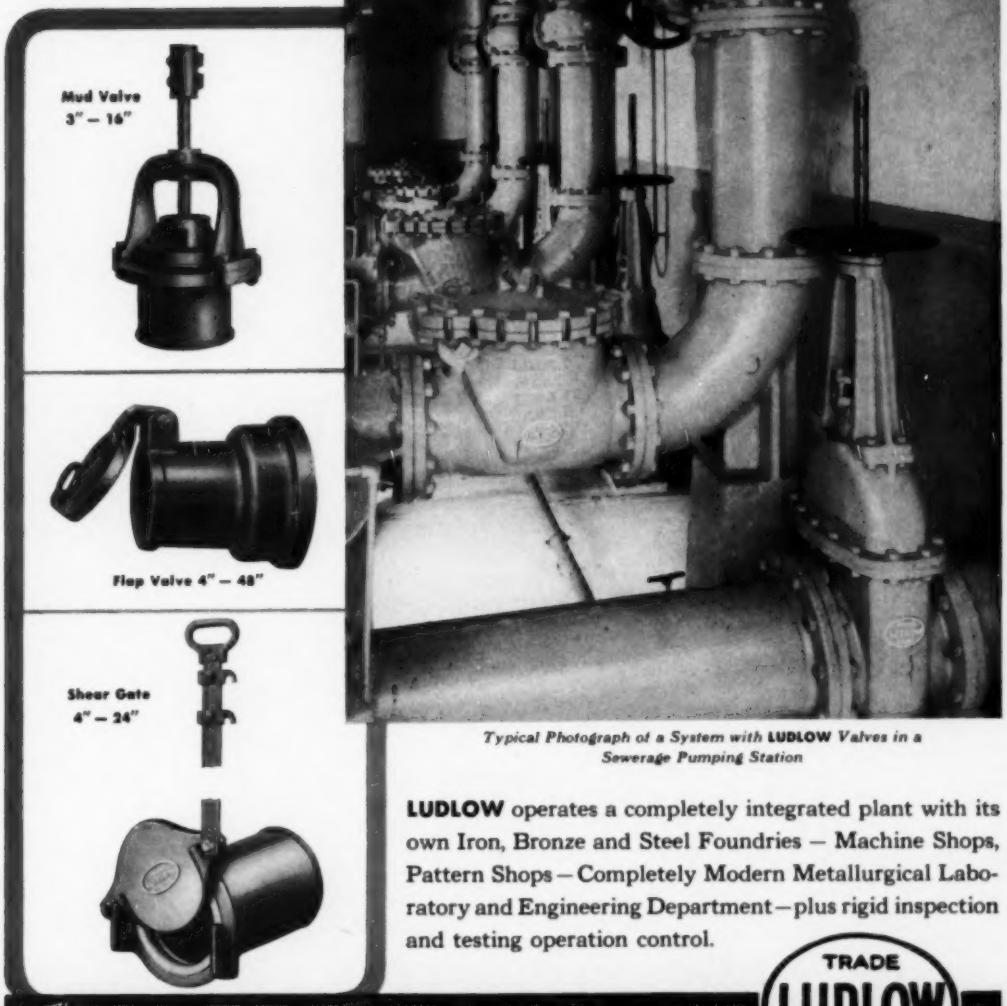
704 RIVERDALE AVENUE • PORT CHESTER, N. Y.

LUDLOW = QUALITY + RUGGEDNESS

for your Sewerage Equipment



Typical Photograph of a System with **LUDLOW** *Valves in a Sewerage Pumping Station*

LUDLOW operates a completely integrated plant with its own Iron, Bronze and Steel Foundries – Machine Shops, Pattern Shops – Completely Modern Metallurgical Laboratory and Engineering Department – plus rigid inspection and testing operation control.

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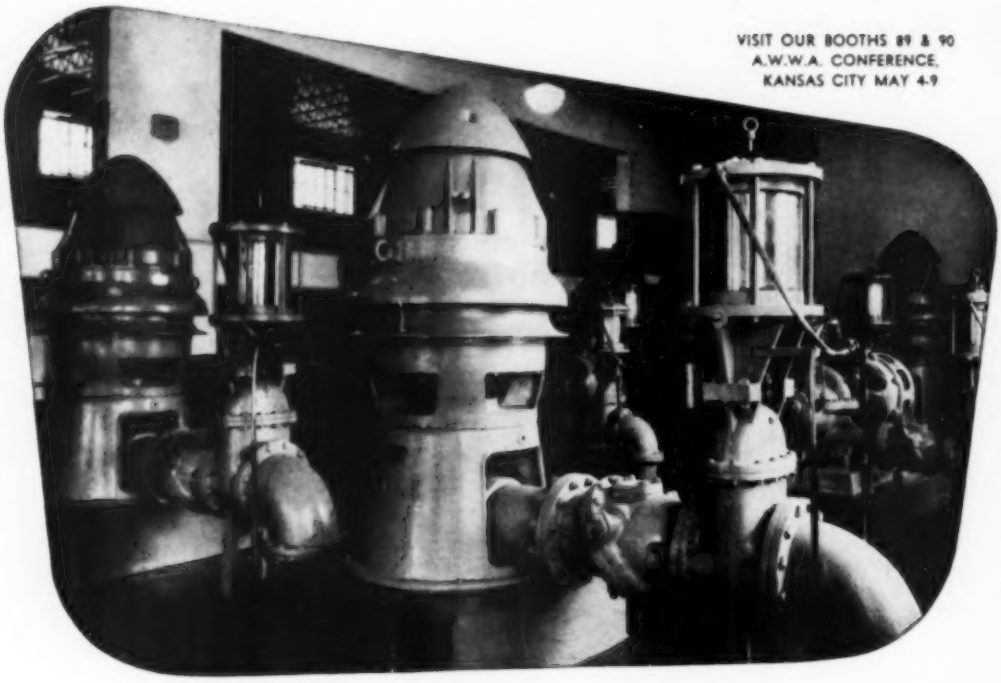

LAYNE PUMPS

serving the city of decatur, alabama

Nine Layne river intake and filtered water pumps have been installed to quadruple Decatur, Alabama's city water supply. Four of these short coupled vertical turbine pumps have a combined capacity of 4-million gallons of filtered water daily.

Catalogs

—on Layne Short Coupled vertical turbine service pumps are illustrated with many installation pictures and diagrams of their use in line boosting, spray ponds, river intakes, cooling towers, engine cooling, etc. A copy will be sent on request. No obligation.

These self priming, space saving pumps are Layne designed and precision built to maintain peak operating efficiency. They are constructed of materials selected for durability and are rugged enough to give excellent service for the years to come.

Like the city of Decatur, a great number of other municipalities, factories, processing plants and chemical works have found Layne pumps to be exactly as described. All are engineered for the job they are to do . . . and all more than fulfill their performance obligations. For further information address

LAYNE & BOWLER, INC.
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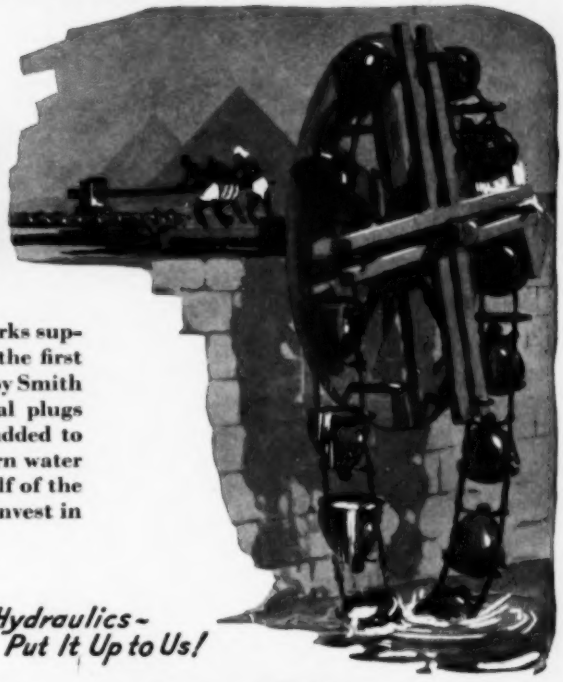
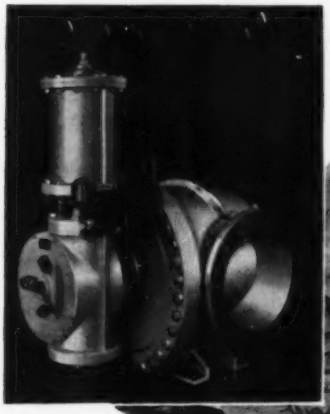
Layne water wells

VERTICAL TURBINE PUMPS-WATER TREATMENT

Modern WATERWORKS *possible with* Rotovalves *by* SMITH



MOVING ever onward, the huge water works supply systems of today have evolved from the first crude inventions of antiquity! Rotovalves by Smith with their full circular openings, conical plugs and electrically welded seat rings have added to the efficiency and reliability of the modern water works and sewage systems. Assure yourself of the utmost return on your Valve Dollar and invest in Rotovalves. Write for our bulletin.



If It's Hydraulics— Put It Up to Us!

S. MORGAN SMITH Co.

YORK, PENNA. U.S.A.

NOTES

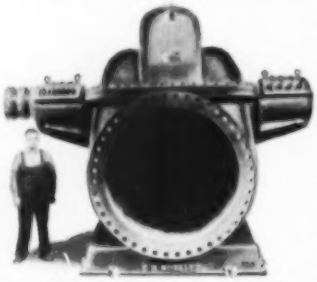
for the engineer's note book

—ON—

Pumping with Economy

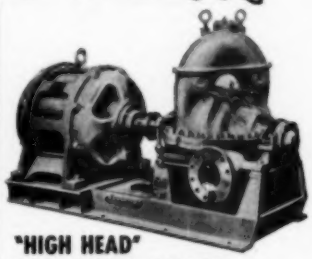
FOR WATER WORKS MEN:

UP TO 90,000 GPM CLEAR WATER CAPACITY
with Wheeler-Economy Horizontally-Split Case Double-Suction Centrifugal Pumps



Wheeler-Economy Double Suction Pumps have records of outstanding dependability in handling clear water or other liquids of low viscosity at moderate pumping heads. These pumps are of the most modern hydraulic design, resulting in high operating efficiencies with little maintenance and long life.

Single stage, double suction, split case design in sizes from 1½″ to 54″. For detailed features, see CATALOG A750.



"HIGH HEAD" IN A COMPACT PUMP
Two Stage Type DMD

Heavy duty, high efficiency with opposed impellers and horizontally split case. Sizes 2″ to 10″ for capacities to 4,000 GPM and heads to 750 feet. Wheeler-Economy DMD Pumps are used in high head water works applications, buildings, hydraulic elevators, boiler feeding, mines, etc. See CATALOG C351.

FOR SEWAGE MEN:

UNSCREENED SEWAGE HANDLED By Wheeler-Economy Non-Clog Centrifugal Pumps

For DRY PIT installations:

Wheeler-Economy Horizontal or Vertical Centrifugal Sewage Pumps have clear waterways from 1½″ to 10″. They pump unscreened sewage, miscellaneous pulp or trash in liquid without difficulty. Where sewage is screened, Mixed Flow types are available for higher speed, more economical operation. Sizes to 36″. **"Sentry"** Type vertical pump with motor direct connected. For dry pit service, not subject to flooding, and to conserve floor space. CATALOG F249.

Horizontal Type for economical installation, accessibility and to simplify maintenance. CATALOG F447.

Open Shaft Type vertical pump with flexible shafting drive from motor. Motor located at distance above pump to avoid possible flooding of electrical equipment and to conserve pump room floor space. CATALOG F249.

For WET PIT installations:

WHEELER-ECONOMY Sump Pumps

Designed in single or duplex units to elevate drainage or sewage from wet pits, sumps, basements, boiler pits, scale and elevator pits, etc. Sizes from 1½″ to 3″ for drainage free from solids. Sizes 3″ to 14″, non-clog type for unscreened drainage containing solids. Sump cover and control arrangements can be supplied to meet any requirements. CATALOG E748 for General Service. CATALOG E345 for Non-Clog.

See Your Phone Directory or Write Us for Name of Nearest Distributor for ECONOMY PUMPS, Inc.

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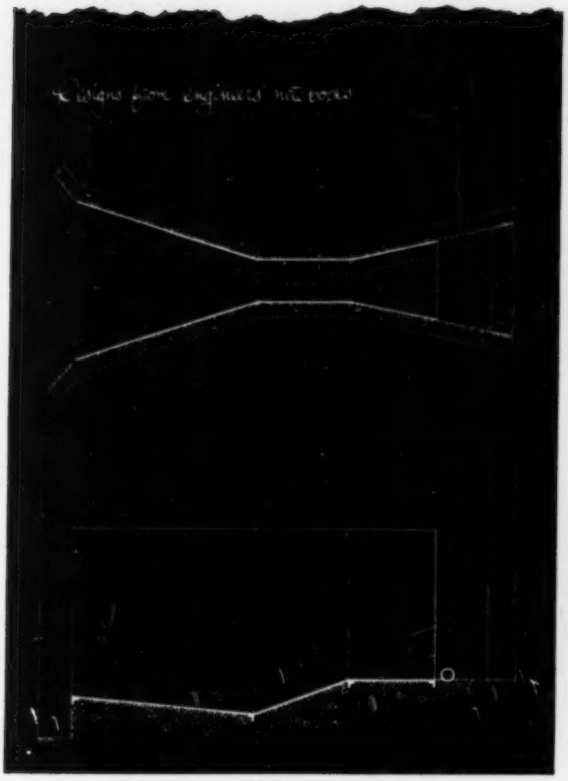
WHEELER-ECONOMY PUMPS

ECONOMY PUMPS, INC. · DIVISION OF C. H. WHEELER MANUFACTURING CO.
19TH AND LEHIGH, PHILADELPHIA 32, PA.



Parshall Venturi Flume lined with EVERDUR for measurement of sewage

Flow measurement in open channels is readily obtained with this Parshall Venturi Flume. It has low head loss and can handle liquids containing solids because the solids can settle at no point. Its accuracy—satisfactory for most waste disposal problems — depends upon maintaining correct dimensions, particularly in the throat.

In providing this flume in the 3 or 4 smallest sizes, with accurate metering equipment, the Simplex Valve & Meter Co. realized that shifting forms, shrinking concrete, and erosion might set up sizable inaccuracies. Their solution was a liner of .1019-in. Everdur* (ANACONDA Copper-Silicon Alloy) sheets welded to angle irons set in concrete. Everdur's smoothness prevents solid accumulations where floor slope causes the flow to lose head. Over a long period of time, this Parshall Flume will provide true flow measurement with minimum maintenance — thanks to the strength and corrosion-resistance of this built-up, light-weight Everdur structure.

Everdur is produced in practically all commercial forms, including casting ingots. It can readily be cast, forged, formed, machined and fabricated by all the usual methods, and is ideal for assemblies such as gates, screens, float chambers, weirs, troughs, manhole steps, gate guides, stems and bolts.

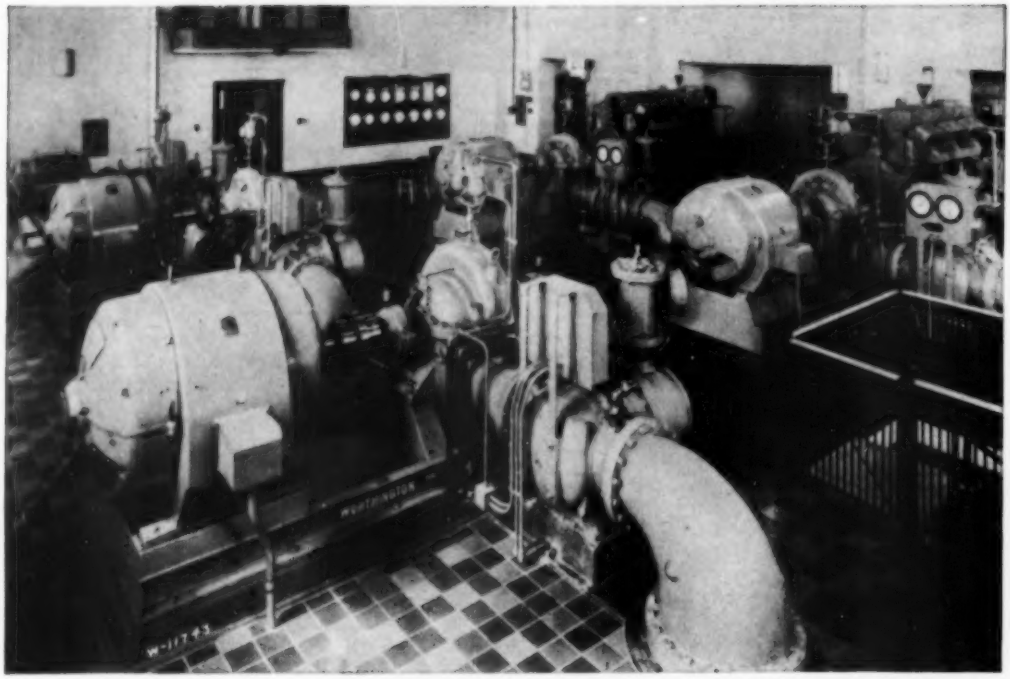
For more information about Everdur, write for Publication E-11 to The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

*Reg. U. S. Pat. Off. 80161

specify Everdur

ANACONDA® Copper-Silicon Alloys

strong—weldable—workable—corrosion-resistant



AS MODERN AS YOU'LL SEE ANYWHERE is this clean tile brick pump building at Evanston, Illinois, Water Works. At the left are three High Lift pumps—6-mgd, 8-mgd and 15-mgd—driven by Electric Machinery motors. At right are two 10-mgd High Lift pumps dual-driven by 350-hp E.M. motors and gasoline engines. Three other 125-hp Wash Water pumps are not shown.

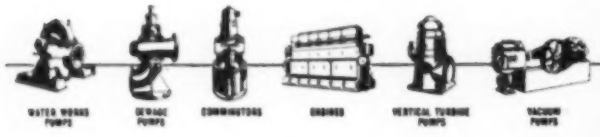
Evanston Water Works– First on the North Shore– boasts modern Worthington-equipped pump room

In the 1890's, it was Evanston, Illinois, that set the pace in water works facilities along the North Shore with the first filtration plant.

Today, this famous midwest city is still known by municipal engineers everywhere for its modern and efficient water-supply installation. The pump room pictured here is a vital part of these facilities.

Built in 1949, the new building houses eight motor-driven Worthington centrifugal pumps including three 10-mgd Wash Water pumps and three High Lift pumps—one 15-mgd, one 8-mgd and one 6-mgd. Two 10-mgd High Lift pumps are dual-driven. The complete water works installation was engineered by Alvord, Burdick and Howson of Chicago, Illinois, Consulting Engineers.

You'd naturally expect cities like Evanston, with reputations for the best in water works facilities, to demand the best in pumping equipment. Their choice is proof that *there's more worth in Worthington*. Worthington Pump and Machinery Corporation, Public Works Division, Harrison, New Jersey. W.2.1

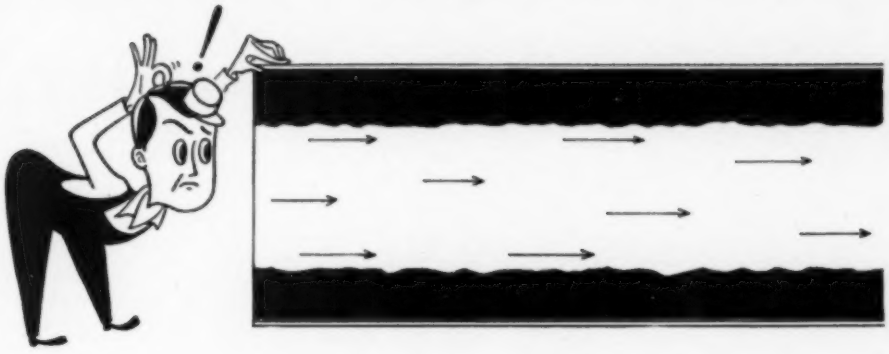


All Major Public Works Equipment Under One Responsibility

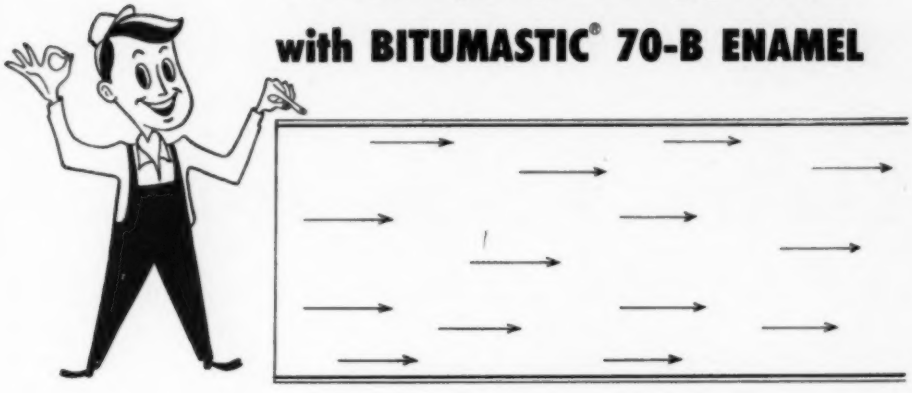
WORTHINGTON

Public Works Equipment

NO WORRY OVER LOW FLOW CAPACITY



...when you protect pipe lines with BITUMASTIC® 70-B ENAMEL



PIPE LINES DON'T "SHRINK" when interior surfaces are coated with a spun lining of Bitumastic 70-B Enamel . . . because this durable enamel *prevents* rust, corrosion, incrustation and tuberculation.

When there's no "shrinkage" of inside diameter, there's no loss of valuable line capacity. Your pumping costs are reduced . . . your pipe line's coefficient of flow *stays* high. It's unnecessary to spend money for *over-sized* pipe in order to allow for anticipated loss in flow capacity.

Further, with a flow capacity *you can count on*, there's no gambling or guessing as to the size of pipe you specify. You select pipe for your water lines solely on the basis of desired capacity.

Bitumastic 70-B Enamel is equally effective in protecting exterior surfaces of pipe lines. It prevents pitting and leakage caused by soil corrosion.

Protect your community's steel pipe lines, inside and out, by specifying Bitumastic 70-B Enamel. Our representative will be glad to assist you in preparing your specifications. If you wish, our Contract Department will handle your coating job for you at the job site. Write for complete information.

KOPPERS BITUMASTIC ENAMELS

KOPPERS COMPANY, INC., Tar Products Division, Dept. 461-T, Pittsburgh 19, Pa.

DISTRICT OFFICES: BOSTON, CHICAGO, LOS ANGELES, NEW YORK, PITTSBURGH, AND WOODWARD, ALA.

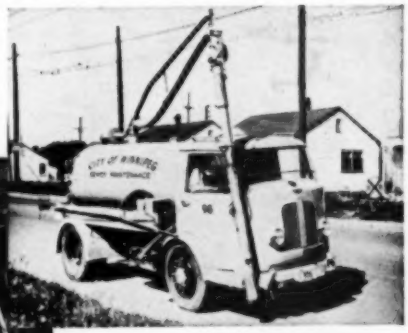
Catch Basin Cleaning Easy and Economical!

This Karrier Catch Basin Cleaner is used by Sanitary Engineering Company, N. Falmouth, Massachusetts for contract cesspool cleaning.

Another enthusiastic user of Karrier equipment for sewer maintenance is the City of Vancouver.

Any municipality that has sewer maintenance problems will agree that the Karrier Catch Basin Cleaner is the answer to their problem for these reasons:

1. Short wheel base for maneuverability; small turning circle.
2. Quiet and slow-running vacuum pump.
3. Hydraulic ram separates solids from dirty water thus increasing the effective capacity of the storage tank.
4. Subdivided tank with compartments for water and sludge.
5. Counterbalanced suction pipe swings to either side or to rear of vehicle.
6. Dirty water can be returned to sewer or used for flushing the next catch basin.
7. Hydraulic ram discharges load from door at the end of the tank when storage space is filled.



Top: For sewer maintenance the City of Winnipeg uses this equipment.

Left: City of Toronto is one of more than 750 municipalities using the Karrier Catch Basin Cleaner.

KARRIER

Catch Basin Cleaner vacuums the dirt out

FOR FULL DETAILS WRITE TO:

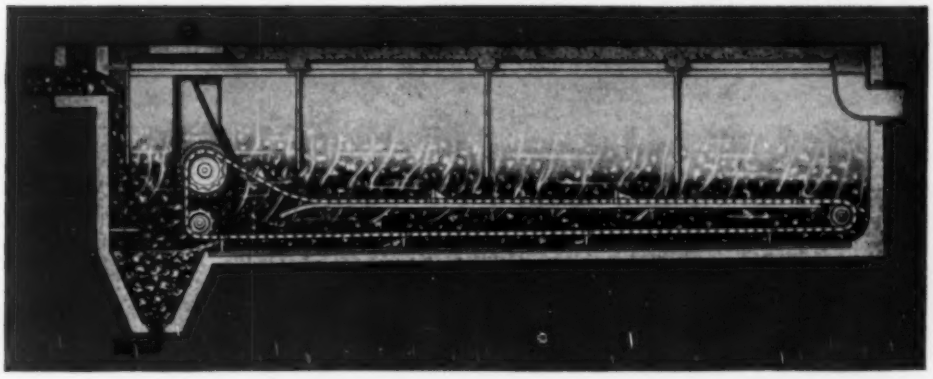
ROOTES MOTORS INC.

27-11 Bridge Plaza North, Long Island City 1, New York (STillwell 6-2305)

INCORPORATING OVER 30 YEARS OF MECHANICAL CATCH BASIN EXPERIENCE.

interested in...

shorter detention periods?
increased tank capacity?
clearer effluent?



you get all 3

with **REX VERTI-FLO**

only verti-flo gives you all these advantages

Detention Periods 25% to 50% Shorter
Maximum Clarity of Effluent
Utilizes Full Tank Volume by Eliminating Short Circuiting
Completely Adaptable for Varying Rates of Flow
Provides Flexibility in Flow Distribution
Allows Sludge Recirculation

Can be installed in existing basins with minimum structural alteration . . . will at least double capacity and improve results

For efficient settling tank operation, more and more engineers are turning to Rex® Verti-Flo®. Here's why—Verti-Flo divides the tank into separate and distinct cells through the use of special troughing weirs and baffles. The solids-bearing liquid is introduced into each cell *at the bottom* along a specific zone. The liquid moves upward—or diagonally upward—gently through the individual cells. The result: improved hydraulic efficiency, which assures a clearer effluent in considerably shorter detention time. Short circuiting is eliminated so that full tank volume is used. Capacity from a Verti-Flo tank is 200% to 400% greater than that of a conventional tank.

For all the facts write for our new Verti-Flo Bulletin. Chain Belt Company, 4610 W. Greenfield Ave., Milwaukee 1, Wis.

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Chain Belt COMPANY OF MILWAUKEE

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DAYTON LEARNED FROM EXPERIENCE

only C-P-P* meets the BIG 3 REQUIREMENTS

Over twenty-five years ago Dayton, Ohio installed an 84" Price concrete water supply pipe line. When this line was uncovered not long ago the concrete was found to be in *perfect* condition, both inside and out. Dayton's complete satisfaction with this and many other concrete pipe lines is why they selected Price Concrete Pipe for a new 72" line for additional water supply.

Other cities are learning too that Price Prestressed Pipe meets *all* the *"Big 3" requirements* for ideal high pressure water lines . . .

1. *Long Life.* With Price Prestressed Pipe, only *concrete* is exposed. When buried in the ground, concrete is ageless as limestone—life is measured in centuries.

2. *Sustained Capacity.* Properly placed concrete has the highest flow coefficient of any pressure pipe structural material —will never corrode or tuberculate under ordinary conditions. The concrete core is there "for good", because it is a structural part of the pipe.

3. *High Beam Strength.* Price Prestressed Pipe makes your water line safe from external loads. It is shatterproof—and sudden and complete failure is all but impossible.

Don't overlook the other advantages of Price Pipe. *It's easy to lay*—can be installed quickly and easily because of its simple, self-centering joint. *It's easy to tap*—any service man does the job with regular equipment and a few accessories. *It's watertight*—the rubber-and-steel flexible joint adjusts to expansion, contraction, vibration and external loads without leaking. *It has great economy*—because of low original cost, low maintenance and extra-long, trouble-free life.

Are your pipes safe from bursting? Are they as ageless as limestone? Will they pump the same number of gallons in 10, 50, 100 years . . . as they did when installed? If you want *all* of the *"Big 3" advantages*, get Price Prestressed Pipe. It will meet every requirement. Write for the facts today. No obligation.

* only CONCRETE PRESSURE PIPE MEETS THE **BIG 3** REQUIREMENTS

1 Long Life
2 Great Strength
3 Sustained Capacity

PRICE PIPE
PRESTRESSED CONCRETE
STEEL-CYLINDER PIPE

Price Brothers Company

1789 East Monument Avenue, Dayton 1, Ohio

Please send me, without obligation, the following literature:

☐ New water supply lines using Price Prestressed Pipe

☐ Complete facts on Prestressed Pipe

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A Report by

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In addition to the many defense and municipal installations made in the past five years in the United States the Roberts Filter nameplate has gone out on equipment installed in a number of other countries:

BRAZIL	GREECE
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Since our 50th Anniversary in 1947, water purification equipment with a combined capacity of a billion gallons a day has been put in service.

You can depend on Roberts Filter.

ROBERTS FILTER MANUFACTURING COMPANY
614 COLUMBIA AVENUE
DARBY, PENNSYLVANIA

NOW—Simpler, Faster, Automatic Titrations!

THE BECKMAN Automatic TITRATOR

Here's another new Beckman advancement in instrumentation—an instrument that runs your titrations for you. It's the Beckman Automatic Titrator—the instrument that makes accurate titrations more rapidly and conveniently than by manual methods.

SIMPLE OPERATION: In a series of titrations, simply fill the burette, place the sample in the beaker—and the Beckman Automatic Titrator takes over from there. Raising the beaker holder into position automatically starts the stirrer motor and begins delivering titrating solution into the sample.

A special circuit electrically anticipates the approaching end point, scaling down delivery of the titrating solution in progressively smaller increments to assure a highly accurate titration. When the end point is reached, delivery of the titrating solution stops and a light shows completion of the titration—*all automatically and without attention from the operator.*

Whether your laboratory is large or small the Beckman Automatic Titrator provides important advantages in your titrating operations . . .

- *It releases the technician during titration, enabling him to perform other operations such as preparing samples, or calculating results.*
- *It eliminates the fatigue caused by close observation required in manual procedures.*
- *It gives objective, reproducible results . . . eliminates errors due to personal factors.*
- *It provides time-saving conveniences for sample handling.*

PERFORMS A WIDE VARIETY OF TITRATIONS—Neutralization, Oxidation-Reduction, Precipitation, Complex-Formation and other types.

NO SPECIAL TRAINING IS REQUIRED—rapid and accurate titrations can readily be performed without special skill or technique.

QUICK, SIMPLE OPERATION—completes many routine titrations in only 1-1½ minutes—even titrations to 0.1% accuracy in 2½ minutes or less. Change of sample is simple, rapid—a single motion raises, locates and secures new sample in operating position.

CONVENIENT, VERSATILE, ADAPTABLE—0° to 100° C temperature compensation . . . adjustable holder accommodates 10 ml to 400 ml beakers or similar vessels . . . instrument may be used with all standard burettes down to 5 ml . . . as many as four delivery units accommodated by single amplifier control unit . . . . uses standard Beckman electrodes . . . electrode holders and delivery tip can be pivoted into any required position . . . ample provision for mounting heating devices or other special equipment.

ALSO A RELIABLE pH METER—the Beckman Automatic Titrator can also be used as an AC-powered pH meter to give accurate readings over the range 0 to 14 pH, as well as millivolt readings from −600 to +1400 mv.

For full details on this new Beckman instrument see your authorized Beckman dealer—or write direct. *Beckman Instruments, South Pasadena 20., California*

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BECKMAN INSTRUMENTS
control modern industries

Beckman Instruments include: pH Meters and Electrodes — Spectrophotometers — Radioactivity Meters — Special Instruments

Hey, buddy, where's the fire?
This is no fire, officer. We're headin' for Kansas City Missouri and the A.W.W.A. Convention.
See you in Kansas City, friends, May 4 to 9. And don't forget to look in on us at Booths 77 and 78.

MATHEWS HYDRANTS

Made by R. D. Wood Company

Public Ledger Building, Independence Square
Philadelphia 5, Pa.

Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

This is the pipe

that's known as the

Taxpayers' Friend

To a tax-burdened public the statement that cast iron pipe is the "taxpayers' friend" is more than a mere figure of speech. To most waterworks engineers it is a cold fact. They know that cast iron pipe in water distribution systems has saved, and continues to save, millions of dollars in local taxes.

The useful life of cast iron pipe is known to be 4 to 5 times the average term of a water revenue bond issue. More than 35 American cities have cast iron mains in service that were installed over 100 years ago. A survey sponsored by three waterworks associations shows that 96% of all six-inch and larger cast iron pipe *ever laid* in 25 representative cities, is still in service.

Fortunately for taxpayers, over 95% of the pipe in America's water distribution systems is long-lived cast iron pipe—*the taxpayers' friend.*

This cast iron water main installed in Richmond, Virginia, 120 years ago, is still in service. Over 35 other cities have century-old cast iron mains in service.

CAST IRON

CAST IRON PIPE

America's No. 1 Tax Saver

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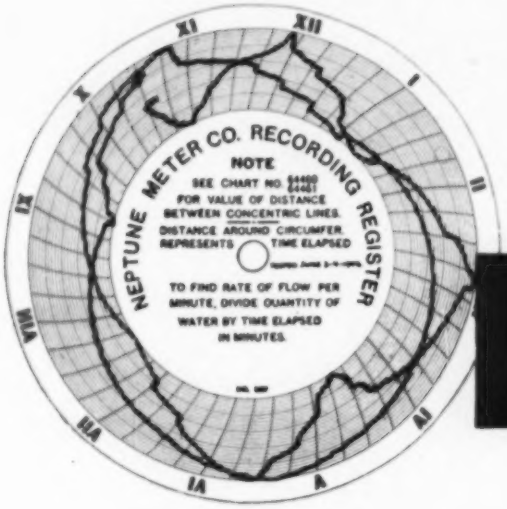

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This chart is an actual record taken from a house with a toilet leak of about 1/10 gallon per minute. It proves the value of an accurate sensitive meter—because a meter not sensitive enough to register at this low rate of flow would never have picked up this leak

—and the water company would have lost the revenue on approximately 149 gallons per day, or about 13,500 gallons per quarter. Instead of 1/10 gpm, leakage might have run as high as 1/3 gpm, with that much more loss to the water company.

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WATER & SEWAGE WORKS

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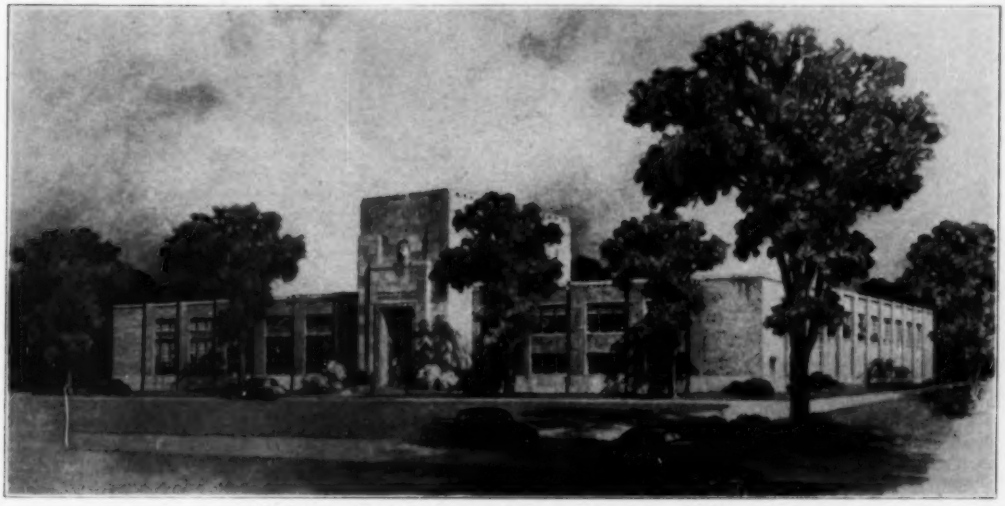


NEW Thos. H. Allen Pumping Station and Iron Removal Plant

The New Thomas H. Allen Pumping Station and Iron Removal Plant of Memphis

Will add 30,000,000 gals. per day of artesian water to city's supply.

by **ELLSWORTH L. FILBY**, *Black & Veatch Engineers, Kansas City, Missouri.*

NOW under construction, the new Thomas H. Allen Pumping Station and Iron Removal Plant at Memphis, Tenn., will be the third iron removal plant and pumping station to supply the City of Memphis with soft, iron-free, artesian water. The existing Parkway Station and Sheahan Station are steam operated with air-lift wells predominantly used. The new station named by the City Commission for the president of their Light, Gas and Water Division, will be an all electric station with stand-by diesel-generating equipment. The main structure is of brick and tile construction on steel framing. The aerator has brick walls on concrete framing, all exposed metal being of corrosion resistant composition. Water is procured from 15 scattered deep wells finished in the "500 foot" Claiborne sands. The iron bearing water is delivered by electric driven turbine pumps through a cast iron collecting system to coke tray aerators. It is then filtered and stored in twin 10,000,000 gallon concrete reservoirs. No chemicals are used in the process. The high pressure station pumps will discharge under constant pressure to the distribution system, which is of the closed type. A centralized control room with panel and bench boards will permit "finger-tip" control of all features. A new 30 inch cast iron feeder main ties into the downtown high value district. The new station is being constructed as a 30 mgd. unit, but is readily expandible to 42 mgd. capacity.

Historical

Memphis, although located on the Mississippi River, has never used it as a source of water supply. Since the discovery in 1887 of the artesian water beneath the City, the public water supply has been from wells in the "500 foot strata" and in a few cases from the "1400 foot strata." The original wells were true artesian wells which flowed above the ground surface. A hotel keeper prior to 1898 utilized aeration and filtration for iron removal. In 1902 Messrs. Hider, Omberg and Bell, acting as an engineering board for the City, reported on the Memphis artesian water supply as follows:

"The water supply is inexhaustible, but the rate at which it can be extracted from the stands at any one point or station is

WELL HOUSE—One of fifteen in the new field

practically limited to 30 mgd., a quantity sufficient to supply 200,000 inhabitants. For a supply in excess of this quantity, it is necessary to install an independent station, pumping into the present mains, at least 4 miles from the present station, from which an additional supply as great as from the first station can be obtained, and beyond this a second or third station may be established, if separated from the other stations by at least 4 miles, and a supply obtained sufficient to furnish a city of any size for an indefinite period."

A typhoid outbreak in 1912, attributed to backwater of the Mississippi entering the supply, and another in 1919 due to a leaking sewer, led the City to develop a safely located supply, with purification facilities. In 1924 Fuller & McClintock, New York engineers, based upon the classical experiments on aeration and filtration by their water purification expert, Wellington Donaldson, designed the 25 mgd. Parkway Station with air lift wells, a pump suction basin and a high service pumping station using steam as the motive power. In 1933, the same engineers followed the same pattern of design for the Sheahan Station of 30 mgd. capacity. These stations are 5.7 miles apart and the Thomas H. Allen station is 6.0 miles from Sheahan and 3.6 miles from Parkway. Thus, a half century later the 1902 engineering recommendations still hold good. From 105,000 population in 1902, Memphis has grown to 410,000 in 1952, with an increase of 101,083 in the 1940-50 decade. The original "Water Board" has been integrated as the Water Division in the municipal Light, Gas and Water Division operating the electric, gas and water utilities.

Artesian Well Supply

From approximately 300 feet beneath the surface at Memphis and extending some 600 feet, there is a portion of the Mississippi "Upper Embayment" which contains water in copious quantity in several so-called "strata." The main aquifer is termed the "500 foot strata" and is generally used by the City and in a large measure by industry. Its sands (Claiborne-Wilcox-Eocene classification) outcrop east of Memphis and roughly west and parallel to the Tennessee River. With a rainfall of from 34 to 71 inches per year and a catchment area that is not extensively cultivated, there is excellent recharge opportunity. The "1400 foot strata" which is generally separated from the "500 foot strata" by 300 feet of impervious clay, has been classified as a "closed aquifer" in the Wilcox sands, and the Water Division is doing everything possible to conserve it for municipal uses. A "2600 foot strata" has been located, but is too highly mineralized for use.

The United States Geological Survey, Ground Water Division, co-operating with the Water Division, has been studying conditions in and about Memphis for many years and maintains an office at Memphis. Just east of Memphis free flowing wells are still possible, but seriously depressed

PIPE ready for construction of additional feeder mains

areas are common in the City due to peak industrial withdrawals. There are now in use approximately 250 private industrial wells in addition to the 83 wells of the Water Division. Industrial wells are seldom metered, but their withdrawals for air conditioning, industrial or process uses, etc., have been estimated at 100,000,000 gallons a day. The average municipal pumpage for 1951 was 45,382,700 gpd., with a peak of 61,457,000 gallons.

The Division test drilled the area in the general vicinity of the new station, and after a study of the distributoin system and the ever increasing industrial development in the vicinity of the Parkway Station, it was decided to develop a site in the southwest part of the City.

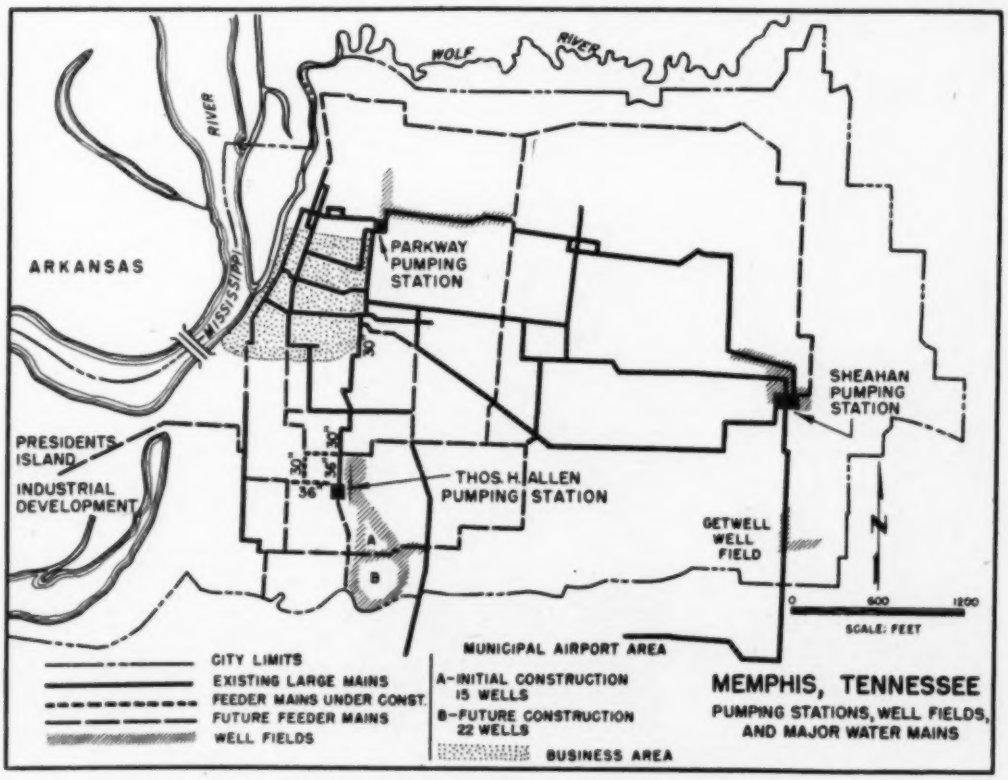
Site Development

The selected 30 acre triangular site was studied as to development and two main structures decided upon, an aerator building on the highest point and the L shaped Pumping Station-Filtration Plant just below it. The Station has a front of 265 feet and a depth of 103 feet, while the filter wing is 173 feet. A railroad spur track was constructed into the site and grading plans carefully developed to give a proper setting in a residential area. Landscape plantings and grass land cover will create the park-like appearance so characteristic of the Water Division Stations. An existing dead-end street is constructed through the site as the principal access road. Behind the Station is a brick Service Building and garage 25 feet by 105 feet in plan. A small creek through the site was enclosed in a 72 inch concrete pipe.

The Thomas H. Allen Station

Supply

The Water Division has designed and constructed, partly by their own staff and partly by contract, fifteen new wells into the "500 foot strata" in the area designated as "A" on the accompanying location plat. Several wells are on the perimeter of the Pine Hills Golf course. Locations have been secured for 22 additional wells in areas "A" and "B," using a standard sub-division lot for each installation in residential areas. Wells are from 700 to 1600 feet apart and average about 1500 feet. They are generally gravel-wall wells, but straight sand point type wells were constructed by the Division. The wells are on the average 400 feet deep. There is from 60 to 80 feet of 12-inch strainer extending below the 18 inch casing of 5/16 inch steel tubing which is cemented in place. Each well is rated at 1,050 gpm. discharge against 265 feet total head. Multi-stage pumping units are set from 180 to 220 feet below the ground surface and are driven by 100 H. P. motors started and stopped from the control board at the Pumping Station through an underground power and control cable system. Each well has a drawdown gage, a discharge meter, electric meter, etc. All starting equipment, transformers, switches, etc., are within the substantial brick well house illustrated herewith. The cast iron well collecting line is from 14 inches to 30 inches in size and so looped and valved as to permit the delivery to the Station aerators of sufficient water to maintain



MEMPHIS' well fields, pumping stations, iron removal plants and major water mains

FILTER BUILDING under construction

full operation. Permanent water level recorders are located in the well field and furnish basic information for the continuing Water Division and U. S. Geological Survey co-operative study.

Treatment

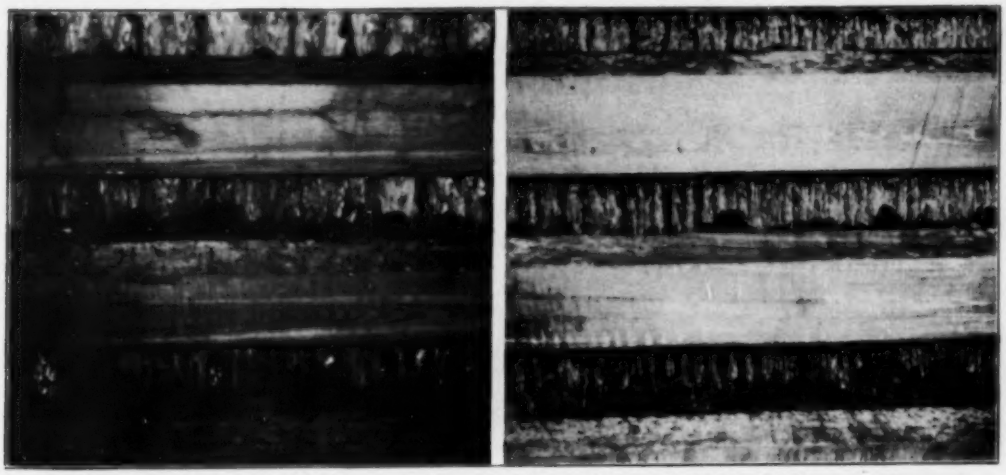
The Memphis rule—"No Chemicals"—has been adhered to. With air-lift wells, secondary raw water pumping and aeration over coke trays, the reduction of carbon dioxide (CO_2) and precipitation of the iron for filtration was relatively easy. As the new deep well turbine-driven "electric" wells will deliver water with 100 ppm. CO_2 and possible traces of hydrogen sulphide direct to the aerators, a full scale experimental aerator unit was built by the Water Division and operated by Mr. R. L. Brown of Black & Veatch to determine the proper media in the trays, method of distributing the water, reduction of CO_2 under varying weather conditions, etc. Final design (see drawing) includes a perforated stainless steel distributing trough and a perforated dosing plate to effect the all important uniform distribution at the top of nine coke trays spaced 1 ft.-3½ in. on centers, thus providing a total fall of 13 feet. Each coke tray is 4 ft. x 8 ft. in plan and has 6 inches of 2½ inch to 4 inch coke. The supporting bottom of stainless steel is a plate perforated with alternate rows of square and round holes and then crimped to give a series of ridges and furrows. The square holes are in the ridges for admission of air to the trays, while the smaller round holes permit small streams to drop to the next coke tray. It was found that a very small movement of air increases the CO_2 removal and so the enclosure of the aerator is minimized and aluminum scroll panels are used to permit maximum unobstructed ventilation. The roof is open except directly over the distributing pans. Inlet riser pipes are valved for proper operation. The dosing rate is to be 25 gallons per minute per square foot at the present full plant load of 30 mgd. The CO_2 is reduced from 100 to less than 10 ppm. by aeration and the pH increased from 5.9 to 7.1. The water then flows to 10 standard, rapid sand filter units each of 3 mgd. capacity at 2.5 gallons per square foot rate. A venturi tube will measure the flow to the filters and a master filter control unit will control the water level in the filter units.

TOP TRAY of coke aerator, showing perforated distribution trough and perforated stainless steel tray bottoms—see detailed drawing

Wash water is stored in 50,000 gallon twin steel tanks in the tower part of the Station. The spent wash water will discharge through a separate 36 inch plant wash water sewer some 4900 feet long to an open drainage ditch. Wallace and Tiernan chlorinators in duplicate are provided for emergency use and for reservoir sterilization purposes. Filters will discharge to twin 10,000,000 gallon covered concrete reservoirs each 277 ft. x 312 ft. in plan with 15.5 feet water dept. A connection will permit bypassing the reservoirs so filtered water may be immediately utilized. All filter equipment, tables, etc. are Simplex and the filter units are equipped with Leopold perforated tile bottoms. The L shaped aerator can be extended to process 42 mgd. and four additional filters can be easily added by extending the filter wing of the Station. All piping is planned for 42 mgd. capacity.

Pumping

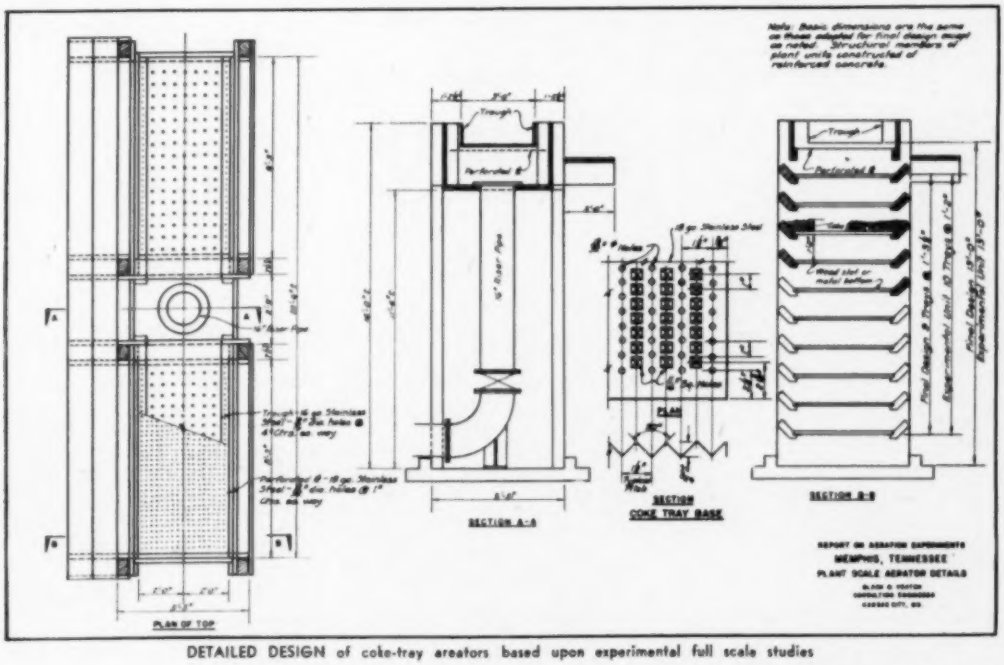
Reliability of operation, to be able to continue delivery of an adequate quantity of water at satisfactory pressure, governed the Station design. Even though Memphis has no elevated storage, it has a very high Fire Underwriters' rating and the Division has constantly followed the policy of doing more than is required from an Underwriters' viewpoint. DeLaval electric-driven pumps in duplicate, each capable of delivering from 5 to 15 mgd. of filtered water and maintaining a constant pressure in the distribution system, are being installed. Each unit is powered by a 600 H.P. variable-speed wound rotor motor with remote controlled drum-type slip controllers with resistors. Each pump has a venturi meter in the



EXPERIMENTAL aerators which supplied design data. Aerator on right reveals why perforated metal bottoms were chosen over wood slat bottom on left. Note uniformity of rain-like distribution on right

discharge line with a cone-type check valve in the throat. A vacuum-type priming system is provided. Space is set aside for two additional units to give an ultimate station firm capacity of 45 mgd. The main power supply to the Station is a 12,000 volt overhead circuit and two separate circuits will be provided from the generating station in Memphis. There will be no overhead power lines on the site.

A metal-clad switchgear is located in a special room and has its bus divided at the center so that each of the two main bus sections can be fed independently or simultaneously from the "normal" feeder. The emergency feeders will each supply a section of the bus. Upon failure of the normal power source, automatic transfer to the emergency sources will be made. As it is possible for the emergency and normal sources to be out of synchronization with each other, interlocking and protective relaying will prevent paralleling the source. Provision is made to permit transfer from one source to the other as desired, without power interruption, provided the sources are synchronized. Power for the well field pumping is fed out of this switchgear. All switchgear is by General Electric.



DETAILED DESIGN of coke-tray aerators based upon experimental full scale studies

Power from this switchgear will be fed to two 2000 KVA 12,000 volt/2400 volt station power transformers. The low voltage side of these transformers will provide energy to the 2400 volt switchgear of standard metal-clad construction, except that it will have two duplicate sections each completely equipped with its own bus and breaker. This will supply power for the 600 H. P. pump motors and to two 200 KVA 2400 volt to 120/208 volt auxiliary power transformers. The emergency diesel unit generator will feed through this switchgear.

Reliability Keynote of Design

With reliability the keynote of the design, the first diesel-generator unit —a Nordberg 8-cylinder 514 RPM unit, direct connected to a 1000 KW 1250 KVA 2400 volt generator—has been provided. Space for two additional units is provided. Dual underground steel oil storage tanks, each of 25,000 gallons capacity, will supply the diesel through fuel transfer pumps. The diesel unit will supply power for high service and well field pumping as well as station requirements. Special attention was directed to "silencing" the diesel unit so as to eliminate any disturbing pulsation during emergency operation. An acoustical ceiling in the pump and diesel room will further dampen operational noise. The unit is so supplied with auxiliaries that it can be "on the line" in a minute.

A central, glass-enclosed control room provides "finger-tip" operation of the Station. Herein is an electrical bench board, a hydraulic valve operating table and wall-mounted instruments to indicate and record operations, such as pump speed, quantity of water being pumped, pressure, depth of water in reservoirs, fuel oil in storage, diesel temperatures, etc. Here pump motors can be started and stopped, placed under manual or automatic control, adjusted as to speed, etc. Control and supervision of outside energy sources is incorporated and remote control of the well field is

COLLECTING line construction in new well field

provided. A special annunciator system is built into the Station. The control room has two entrances and the visibility and lighting problems have been given special consideration.

Pumps will discharge into a cast iron looped header, properly valved for full reliability, and discharge through four 36 inch cast iron feeder mains to the distribution system. One 36 inch to 30 inch feeder main has been constructed to the principal business area of the City, and another similar main is under construction. Two "spare" feeders are built to the station property line. To secure satisfactory drainage, a stream through one corner of the property was encased in 72 inch reinforced concrete pipe and the two small drainage culverts beneath the high railroad fill were replaced by jacking this 72 inch pipe through the fill by means of two 100-ton jacks. Drainage from the station has been arranged so that a break in the supply conduit or in the discharge header will not flood the pump discharge basement.

Other Station Facilities

One of the features of the Station is an assembly-instruction room for Water Division employees. There are the usual sanitary features and locker rooms. The manager of the plant has a small separate office and there is a small laboratory room for tests that must be made on the spot. The Division's main laboratory is at the Parkway Station. A separate battery room is provided for D. C. power to operate the switchgear, all D. C. control equipment and emergency station lighting. The station heating will be by two natural gas fired steam boilers, both of which will have standby oil firing facilities. A hydraulic-operated freight elevator will permit removal or storage of heavy materials in the basement. Loading docks and paved areaways permit truck traffic behind the station. A single crane will serve all pumps, diesels, basement piping areas, etc. With two existing steam operated stations and the new electric with diesel standby station, Memphis is well equipped for this dawn of the Atomic Age.

Project Management

The Light, Gas and Water Division, Thomas H. Allen, President, is adding the Station, well field, etc., to the municipal water system. C. M. McCord is Director of the Water Division, and Justin J. Davis is Chief Water Distribution Engineer. Other officers of the Light, Gas & Water Division are S. S. Pharr, Vice Pres.; I. J. Lichterman, Commissioner; N. W. Wade, Sec'y.

The prime contractors on the Station are the R. P. Farnsworth & Co. of New Orleans, La., and E. W. Bacharach Co. of Kansas City, Mo.

Design of the Station and well field collecting main and power supply is by Black & Veatch, Consulting Engineers, of Kansas City, with Furbringer & Ehrman, Memphis Architects, handling architectural matters for Black & Veatch. Delber L. Blackwell is Project Engineer, and John J. Knoll is Resident Engineer in charge of supervision of construction for Black & Veatch. Cost will be in excess of $6,000,000, with completion scheduled for the end of 1952.

A.S.A. Issues Three Standards in the Field of Pipe Flanges

Three American Standards in the field of pipe flanges and fittings have just been approved by the American Standards Assn., New York, N. Y. They are: American Standard Nonmetallic Gaskets for Pipe Flanges, B16.21-1951; American Standard wrought Copper and Bronze Solder-Joint Fittings, B16.22-1951; and the American Standard Malleable-Iron Screwed Fittings, 150 lb., B16.3-1951.

Now for the first time nonmetallic gaskets can be manufactured and purchased according to American Standard sizes. These gaskets have always been manufactured according to individual specifications.

Copies of the three standards will be available from the American Standards Association, 70 East 45th Street, New York 17, N. Y., and the American Society of Mechanical Engineers, 29 West 39th Street, New York 18, N. Y. The prices per copy are: Nonmetallic Gaskets for Pipe Flanges, B16.21-1951, 60 cents; Wrought Copper and Bronze Solder-Joint Fittings, B16.22-1951, 75 cents; Malleable-Iron Screwed Fittings, 150 lb., B16.3-1951, $1.00.

> Contentment makes poor men rich; discontentment, rich men poor.
> —*Ben Franklin*

Critical Materials For Water and Sewage Works

Steel and Aluminum Easier; Copper Tighter.

by GERALD E. ARNOLD,* *Director, Water Resources Div., National Production Authority, Washington, D.C.*

DURING WORLD WAR II the War Production Board found it necessary to restrict the civilian use of critical materials in order to expedite the Nation's defense effort. Part of the function of the War Production Board was to activate the Controlled Materials Plan as a measure, designed to equitably allocate such critical materials to the most essential industries and services.

With the advent of hostilities in Korea, it again became necessary to control certain critical materials because of the demands for defense production. The National Production Authority was established by Act of Congress as a part of the Defense Production Act of 1950. The National Production Authority, which is a part of the Department of Commerce, is only one of several agencies of the government operating in the materials control field at this time. Certain delegations of authority were given to other Federal departments, such as Agriculture and Interior.

In the early phase of the operation, the water and sewage facilities were handled by several different agencies. During the summer of 1951 the Water Resources Division was established as part of the National Production Authority and is now responsible for the allocation of materials to the domestic and industrial water and sewerage systems of the country.

The Water Resources Division operates in two branches: one, known as the Program Requirements Branch; the other, the Technical Engineering Branch. The Program Requirements Branch studies the probable needs of the water and sewerage field, tabulates the information obtained from applications received from operators, and prepares the material requirements under which this division receives its allocation of materials for use in water supply and sewerage systems. The Technical Engineering Branch is the one that handles the applications submitted to the division for construction permission and allotments of materials. The Division was first organized under the direction of Harvey S. Howe. The writer succeeded Mr. Howe in September 1951, as division director.

The division, as a claimant agency, receives its allotment of materials under the Controlled Materials Plan and thereafter keeps its own books on reallocation of those materials to the operators. Each application that is approved by this division is screened for the accuracy of its requirements and the need of the individual project. When materials are allocated under this plan, they are deducted from the balances within the division's books. By this method, an allocation of materials means that there is current production capacity somewhere in the country to permit the operator to obtain his materials. It also means that procurement of such allotted materials can be expected on a scheduled delivery basis with some degree of certainty.

Construction Materials— "A" and "B" Products

Construction materials fall into two categories: those known as "A" products and those known as "B" products. "A" products are those materials specifically fabricated for the particular construction project which requires final fabrication in the field or on the job—water tanks, for example. "B" products are those items normally manufactured by producers as more or less standard items and which can be shipped to the job in completely fabricated form—such as valves, hydrants, pumps, etc. In making a request for materials for a construction job, an allotment of materials is not specifically made for the B products to be used on that job. Instead, the operator should indicate on his application in dollar value the cost of such B products to be used in the construction.

How to Operate Under the CMP

The first thing an operator will desire to know is how he can continue to operate his system under the CMP. CMP Regulation 5 describes the provisions under the Maintenance, Repair and Operation (MRO) section of the regulation. An operator may obtain for MRO up to 30% of the dollar value of the materials he used during the calendar year 1950. He may choose to use such materials either on an annual basis or on a quarterly basis. If he establishes a seasonal quarterly quota, it can be 120% of expenditure during corresponding quarter of 1950. Once having selected the basis of operation, he may not change that basis without written approval of NPA.

Because of increased business or other cause, an operator may obtain relief from the restrictions of the MRO provisions by making application to NPA for such relief and fully explaining the reason why such relief is necessary. This should be done as far in advance as is possible. If, due to some emergency, an operator must obtain unexpected relief from the MRO provisions, he should make such requests by telegraph.

Two Classifications of Construction Projects

Under construction, there are two categories of construction projects: what is known as minor capital construction or small construction projects and, secondly, what is known as major capital additions. Under minor capital construction, an operator may self-certify the materials needed for that construction project provided he does not exceed five tons* of carbon steel and/or 200 pounds of copper; also, provided the total cost of the building *equipment and materials* (exclusive of labor, transportation, etc.) does not exceed $15,000. Under this provision, the operator may place an order with his supplier and authenticate it with the statement, *"This order is certified under CMP Regulation 6, allotment symbol U-8."* Under the provisions of this self-certification there must be some controlled materials (so far confined to steel, copper and aluminum) in the

*Former Director, San Diego, Calif., Water Dept., on leave of absence.

*Increased from two tons to five tons in the new draft of CMP Regulation 6 just issued on March 5th, as covered by an insertion under "Late Developments" supplied by Director Arnold just as we go to press.—Ed.

project. The B products to be used in the construction may be self-certified along with the controlled materials in amounts not exceeding the dollar value limit of $15,000 for all materials and equipment. This dollar expenditure limitation is new, as set forth later.

If the proposed construction project is to require CMP materials beyond the limitations outlined above, the operator must file an application for construction permission and an allotment of materials, using Form CMP-4C. The form should be filled in quadruplicate, sending all four copies to the Water Resources Division of NPA in Washington. The form should be complete in indicating essentiality of the propsed construction, a brief description of the particular project to be built, and a carefully screened list of the materials required. If the work is essential and permission is granted by the Water Resources Division, there will be no reduction of the materials covered in the application provided they are reasonable and accurate. Do not pad the materials requirements thinking there may be a percentage cut in the allocations made. It is the policy of this division to allot sufficient materials to complete a project. Percentage cuts are not made in the requirements stated by the engineer or operator. See that the application is properly signed. If the owner delegates the authority to a consulting engineer, a contractor, or other party to apply on his behalf, there must be a letter of authorization accompanying the application, certifying that the agent is authorized to apply for and on behalf of the owner. The allotment symbol T-8 will be assigned by the Water Resources Division to materials granted under this provision.

What to Do Under Emergency Conditions

In the event of an emergency requiring restoration of services damaged or destroyed for any cause, telegraphic authorization can be made and materials allocated for emergency repairs. In this event, the operator should contact the Water Resources Divison by telephone or telegraph stating the nature of the emergency and outlining materials needed. Confirmation of this action should be made as soon as possible by filing Form CMP-4C with the Water Resources Division.

The Question of Substitute Materials

While this is a period of emergency requiring the curtailment of the uses of critical materials, water and sewage works operators should, as far as possible, follow a standard design practice. Water mains should be of sufficient size to render adequate fire protection. Buildings and structures should be designed of their usual permanent materials. They should, however, make as much substitution of non-critical materials for critical materials as is possible. Copper will be a difficult material to obtain for some time and substitution of other materials for copper should be considered. Copper service tubing to connect from the main to the property line should be used only under pavement. The use of certain plastic materials for service connections should be investigated. Substitution of alumnium for copper wire in electric transmission lines should be considered. By following reasonable use of critical materials it is believed that the essential water and sewage services may be continued without serious curtailment.

The general situation on materials seems to be easing in some lines. Steel is becoming more readily available and indications are that by the end of 1952 some forms of steel will be in plentiful supply. There is still a shortage of steel, structural and plate, and consideration should be given to the use of reinforced concrete construction in order to avoid unnecessary use of these more critical materials. Aluminum is becoming more readily available, but copper will continue to be tight due to the limited copper production capacity of this country and the increasing military demands. As materials become more readily available, the National Production Authority's regulations regarding their use will be changed, easing the restrictions in accordance with availability of materials.

Supplies of chlorine are available to water and sewage works operators under NPA Order M-31. This is an order issued by the Chemical Division and restricts the use of chlorine for most operations. Water and sewage works operators, however, are permitted to use as much chlorine as they used during 1950. If because of increased water consumption or change of water quality or for increased demands for sewage treatment, an additional supply of chlorine may be obtained on request. If any operator has any difficulty obtaining chlorine, he should immediately get in touch with the Chemical Division of NPA and also the Water Resources Division. The same situation applies to filter alum, but water operators are permitted to obtain as much alum as is necessary for their uses.

Late Developments of Import

Effective March 5, a new draft of CMP Regulation 6, which is the general construction order for NPA, was issued. This new order changes a number of the provisions under which water and sewage operators have been functioning and they should immediately become familiar with the new draft. The principal changes are that self-certification has been increased from two to five tons of steel for minor plant additions, but the dollar expenditure limitation of $15,000 for building materials and equipment *of all classes* (A and/or B products), for self certification projects in the minor plant additions category, has been added.

Another change is that up to 100 lbs. of aluminum is permitted where no copper is required. A combination of 100 lbs. of copper and 50 lbs. of aluminum is also permitted. In short, two pounds of copper or copper base alloy must be dropped out for every pound of aluminum that goes into such minor construction projects.

There is also under preparation a proposed M-order for water and sewage works operators and it is hoped that before long this M-order will be in effect. Under the M-order, water and sewage works operators will be permitted to operate on a more liberal scale than applies to the general construction industry. As soon as the new order is released, you will be notified through trade journals.

The Water Resources Division is anxious to do all it can to aid and assist water and sewage works operators in conducting their important operations. Obviously, with some 30,000 water and sewage systems in the country there is insufficient material for all proposed construction projects. Every effort is made to approve essential projects and engineers and operators may rest assured that their applications are all given careful scrutiny and consideration.

Without controls and regulations, the materials procurement situation would be very serious. Controls are necessary in order to make certain that essential projects and operations faced with an emergency get the materials needed with the degree of assurance that the Controlled Materials Plan provides.

RECEDING WATERS at Turkey Creek Pumping Sta.—and the heck of a mess inside.
(High water was above box cars. Note two porkers stranded on what was a roof on temporary structure.)

Disaster Plans in Water Works Operations

Some Experience Gained During and After the Disastrous Flood of 1951 at Kansas City.

by MELVIN P. HATCHER, *Director of Water, Kansas City, Missouri.*

IN this article it is the writer's intent to deal with disaster plans for the water works operator,—plans designed to minimize damage and service impairment and to hasten the restoration of service if the disaster has resulted in the interruption or partial interruption of service to any group of customers. Much that is specific in this article comes from experience gained during and after the 1951 flood in Kansas City. Most of the plans that are dealt with here have to do with the possibility of a flood of major proportions. However, many of the precautions that need to be taken against the chance of a flood can be extended rather readily to other kinds of misfortunes that can befall a water works property.

First though, the point should be made that the scope of this article does not cover operations for Civil Defense, the latter being a branch of disaster preparedness all its own. Although much that will be said here will have some application in Civil Defense, the article is not written from that viewpoint. Rather this article will concern itself mainly with floods and in a more general way with the kinds of disasters that result from fires, hurricanes, earthquakes and other accidents that can and do disrupt the operations of water works properties. In the latter category for instance are broken water mains in pump pits and a danger that we are reminded of by recent accidents in Elizabeth, N.J., —that of falling aircraft.

Even the most carefully prepared plans are apt to be inadequate in case of a disaster. On the other hand, those who experience disaster usually feel that they would know better how to combat a disaster if given a second chance,—which they pray will never be their lot. Possibly then, if we record our thoughts in these matters they may in time grow into something quite helpful to our fellow water works operators.

Mr. L. P. Cookingham, City Manager of Kansas City, flew to Texas City during the disaster of April 1947. He came back with the idea that every city—and his city particularly—should have a disaster plan, ready in advance of need. Some work was done in this direction, but before the plan could be perfected the idea was superceded by the need for a Civil Defense organization. While Kansas City did not have a complete disaster plan in readiness when it was visited by the flood in 1951, it did have some plans and much that was learned at Texas City was used to good effect in the emergency flood plan. Supplementing this the experiences gained at Winnipeg, Canada, during the serious flooding of that city was placed at the disposal of our city authorities.

Top Level Organization

The attention that this article purposes to give to disaster plans for the water works operator would be incomplete without a discussion of the overall problem of community organization for recovery from a disaster. This subject may be introduced by the observation that each community should have a disaster plan. In the smaller communities the plan will be quite simple and in the larger cities quite complex. In the latter case the scope and complexity suggests the need for manualization. Only on this basis could plans be considered complete. And, too, no matter how adequate the water work's operators own disaster may be they may be doomed

to failure unless the community has made adequate preparations for its part of the work.

The scope of this article does not permit probing of all possibilities along the lines stated but some points can be made. There must be a central authority; more often this will be the Mayor or the City Manager. Each community includes many agencies that will be called upon to take a part in the recovery work; these should be catalogued and each should know its part in the disaster plan. The plan should include a Control Center and complete plans for communications from the center.

It should include the mechanics of dealing with some of the major problems. One of these is the handling of traffic. That aspect of the 1951 flood will long remain in the memory of the Kansas Citians: The bumper-to-bumper, snarled and slow-moving traffic in all the downtown area from early morning before the flood to late at night on the day of the flood. It seriously hampered many efforts; it interfered with the rescue and salvage efforts and it made it almost impossible for persons needed in property-protection operations to move from one part of the city to another. Welders needed at the main water treatment plant across the river from Kansas City gave up after several hours efforts to reach the plant and returned to their shops. The disaster plan should come to grips with this as a number one problem before the need for correction has become acute.

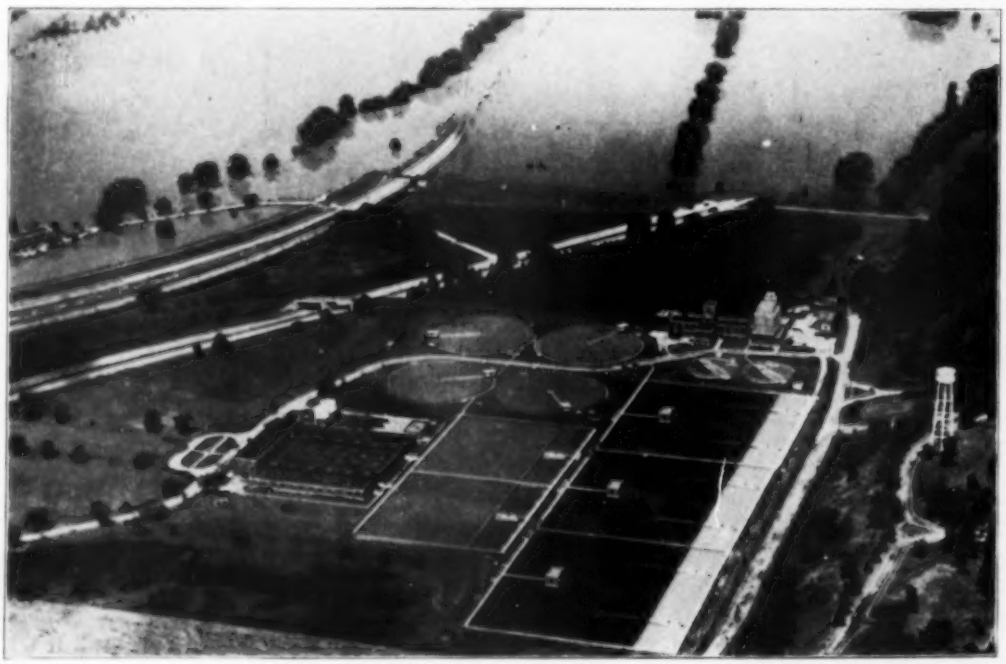
The disaster plan should anticipate the problems attending the emergency issuance of orders, news releases and bulletins regarding the disaster. This is most important. In the smaller communities, the water works operator may need to prepare most of his own publicity but in any community this phase of disaster operation is worth all the careful attention that can be given to it. Complete, prompt and frank publicity is a palliative to the public's frayed nerves. They will cooperate if they know the dangers and what is being done to overcome them. And, they are apt to be quite intolerant of any failure on the part of public officials to keep them informed.

Kansas City evolved splendid information plans in its 1951 flood. These plans had no advance planning but they were undertaken with certain advantages. Kansas City had a reservoir of young and trained manpower in its Research and Budget Department,—12 interns and analysts in public administration. With two trained and experienced supervisors working around the clock at Emergency Flood Headquarters these aides helped to prepare and carefully process over 100 orders and news releases for radio and press in the two weeks following the flood. Much confusion was overcome by the simultaneous release of this information to representatives of the radio and the press.

"Disaster Corps., Inc." and Its Recommendations

Disaster plans may well include the legal framework needed for marshalling the forces of labor and labor supervision. The word "disaster" implies destruction of property and its aftermath is most likely to require a well-defined plan that will provide for the speedy assembly and for the most purposeful use of manpower and equipment. The implementation of this plan will require the legal arrangements necessary to the formation of a corporation. This is essential to the grouping of the forces ready and willing to serve their community. It will permit them to make contracts, assume liability for their actions and insure the men that will do the work.

Such a group was formed in Kansas City in 1951. They called themselves "Disaster Corps, Incorporated" and they were made up of an alliance of the forces of labor with those of the contracting and building industry in Kansas City. Labor agreed to work for $1.50 an hour irrespective of classification, contractors agreed to furnish



MAIN Water Purification Plant of Kansas City on the Missouri. River Intake seen on left.

supervisory help without charge and to furnish equipment at half the going rate.

This venture was singularly successful. Disaster Corps, Incorporated was the first rehabilitation force to enter the stricken area. In six days following the flood, their 16,000 man-hours of work with 375 pieces of equipment bridged the gap between desolation, disorder and some 5,000 or 6,000 dead animals on the one hand and a semblance of order and reasonable safety from fire and disease on the other.

The point here is that the need should be anticipated. It happens that little time was lost in Kansas City because DCI was organized while the flood waters were receding. However the flood struck on Friday and the incorporation of the organization was not complete until late on Monday. Most of such disaster plans—particularly incorporation and the arrangement for insurance—can be arranged ahead of a disaster.

When the work of DCI was finished its sponsors published a splendid brochure recording its accomplishments and ending with certain recommendations which it aptly described as "hard-earned". They are included here because they serve so well to round out this phase of disaster preparedness:

(1) Close the stricken areas to all persons until fire and health hazards are abated and emergency clean-up is well towards completion.

(2) Persons whose homes or business are affected by a catastrophe should be represented directly or indirectly on the policy-making levels of the rehabilitation group.

(3) To coordinate the respective problems, City specialists in health, engineering, fire, police, etc., should work closely in a disaster unit. The Federal Government and other interested groups such as the Red Cross and Chamber of Commerce should furnish similar coordinators.

(4) Public relations is an important integral part of a program.

(5) An authorized and legally-constituted three-man board, including a disaster unit representative, with rigid and almost autocratic authority for one purpose: To control the issuance of passes to the stricken area.

(6) It is strongly suggested that all future disaster corps do what DCI has done—say "NO" to all pressure for favors which could mitigate against the common good.

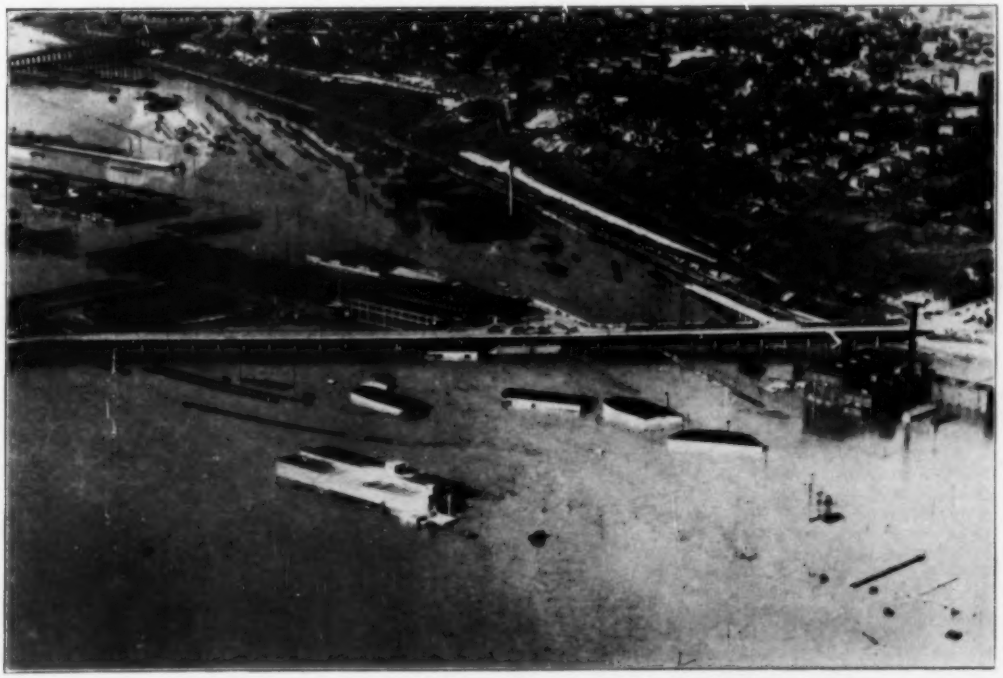
When the work of Disaster Corps Inc. was finished it published a splendid booklet ending in recommendations well worth reading by communities wishing to organize themselves for recovery from a disaster.

The Water Works Operator's Disaster Plan

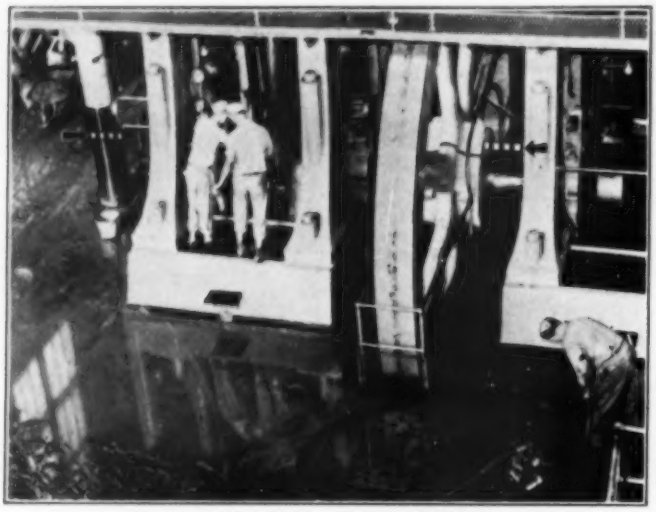
Each water works property should be surveyed from the standpoint of its vulnerability to disaster. These surveys should embrace a thorough combing of these properties in search for conditions that might result in interruptions of service. They will be aimed mainly at the liklihood of flood damage but they may well include some other dangers such as have previously been referred to.

Plans for coping with these dangers should be reduced to writing. This does not necessarily mean that the result will be a manual. Rather it is more apt to be one or more bound volumes or even more likely a file which the water works operator will know to be the source of practically all information needed in case of an emergency. The following will suggest the kinds of information to be included in the file:

(1) Main property drawings and especially all drawings needed to key flood elevations for the area to the property's plant elevations. It will be sufficient in many cases if the informa-



FLOOD PEAK. Turkey Creek High Service Pumping Sta. on right, silent and abandoned.



RESTORATION of Turkey Creek Station under way.
Note arrows indicating high water mark on triple-expansion pumps submerging main bearings

tion is portrayed in sketches referring to the necessary larger drawings or photostatic copies of the larger drawings.

(2) Sand bagging or temporary dike plans with complete lists of the materials required to build them.

(3) Check lists of emergency equipment and materials required. Of course duplication of equipment must end somewhere but this list may well include standby pumping equipment likely to be needed in case of a failure of some link in the water supply chain. It will also include boats, "walky-talky" radio equipment, life belts, portable chlorinators and other emergency equipment.

(4) Check lists of specific steps to be taken in case of or in anticipation of a flood. This will vary with each property but it may refer to valve closures, washing filters if this operation is interfered with by high water, moving electric motors to *safe* elevations (some motors were removed prior to the damaging phase of the 1951 Kansas flood but were then stored too low) and moving transportation and other movable equipment to safe areas.

(5) Regulations to insure that key employees can be reached promptly.

(6) Instructions to supervisory employees to carefully log all operations during the emergency period. The use of voice recording equipment is particularly helpful for this operation.

(7) Instructions regarding photographic recording. A complete pictorial record is apt to stand the water works operator in good stead.

(8) Regulations regarding the sterilization and use of tank trucks. Street sprinkling and milk trucks are likely to be the best source of containers for emergency supplies.

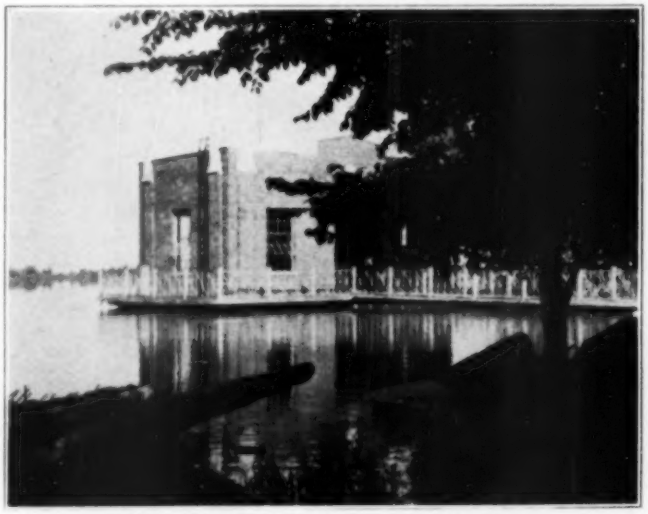
(9) Evidence of the availability of small complete water treatment units.

(10) Plans for emergency headquarters. Most likely even a minor disaster and certainly any involvement of water services will result in an avalanche of questions. Plans should include prompt provision of the staff and the equipment needed to accept and answer these questions by telephone or in person. Even though the water works operator's plans are a part of an overall community plan, he should be as certain as he can that his needs have been anticipated. They may for instance involve major changes in telephone equipment as well as other means of communications.

Curtailment and Restoration of Service

A disaster more often than not will involve a total or partial impairment of water service. In the latter case this will require an apportionment of the available water supply by classes of customers. Of course the need of water by home owners for sanitary and cooking purposes will have top priority. It will help however in the administration of use restrictions if the disaster plan can be made to also include a classification of the commercial and industrial customers according to the essentiality of their need and their total water demands.

Kansas City's first General Order which was released within four hours after the partial failure of the water supply read as follow: "All offices and business establishments, except those which are essential to health and food services, are requested to discontinue operations as a means of conserving water and to remain closed until a better knowledge of the situation is developed. Exceptions to this order are restaurants, drug stores, essential food stores, hotels, newspapers, radio stations, medical offices and services, public utilities and others



RIVER INTAKE barely kept its nose above high water.
Note on page 146 a picture of emergency enclosure built around electric motors to prevent flooding

SEVENTEEN feet of river above ground level.
The Diesel powered crane is used for unloading coal from gondolas into bunkers

of this nature. All residents of Kansas City, except those engaged in essential operations, are requested to go home and remain there in order to reduce traffic congestion which is hampering the emergency operations."

It should be emphasized here that such orders should be clear and concise; any lack of clarity is translated quite promptly into a great many 'phone calls which take the time of administrative help that is seriously needed elsewhere. There were a few appeals from Kansas City's first order; one was whether the manufacturing of ice cream constituted a food-processing operation, another was from an ice manufacturer making ice needed for the preservation of food.

About four hours later the first General Order was supplemented with more specific instructions. They listed first the several categories of service that were to be permitted to continue in operation. The reference to laundries was on this basis: "Laundry and cleaning establishments shall be closed to the public except to deliveries of already finished work but will continue to handle hospitals, hotel and other types of institutional work."

One rather important situation developed out of this laundry order. The laundry owners and dry cleaners association with full cooperation from the laundry workers union initiated a plan whereby three laundries would do all of this work and others would remain closed. There were only three violations of this order, these were quickly corrected, and the whole plan served quite well.

The closing order included this provision. "No air conditioning equipment using water shall be operated any place in the City of Kansas City, Missouri whether by business establishment, hotels, apartments, or private homes". Several points pertinent to a disaster plan developed out of this order. Kansas City's maximum daily demand for water used for air conditioning is calculated to be on the order of 17.5 to 20 million gallons per day. There was complete cooperation with the order while parts of the City were out of water, but upon partial resumption of service there was experienced a considerable and quite insistent clamor for removal of the ban on water use for air conditioning. This came mainly from those having circulatory systems and most of the calls came from hotels and restaurants.

As a way of coping with this situation, it was agreed after consultation with the officers of an association of equipment dealers and contractors that installations having circulatory water conserving systems would be allowed to operate on a permit basis. This permit plan relied on certification by representatives of this association as to the qualification of applicants. These representatives and employees of the Water Department worked at top pace from dinner time to midnight one evening to process 700 permits involving about 21,000 tons of air conditioning equipment. These permits, issued in the form of posters, were displayed by the users of air conditioning equipment on their premises. One of these permit posters is here shown.

The reaction to this plan was not unexpected but it does deserve consideration in any disaster plan. Many users without permits also started their equipment and this was at a time when the water pressures were adequate for consumer use but there was no margin of safety for fire protection. It became necessary to discontinue service to a few users in order to enforce the order. However it was felt that continued operations on this basis would have been difficult. Violations in individual offices were most difficult to control. Fortunately it was possible to allow all users of air conditioning equipment to resume operations shortly after the initiation of the permit plan. It seems quite desirable that any disaster plan should include a complete cataloging of air conditioning equipment, such a record should classify the customers with air-conditioning installations and reveal which installations are of water conserving and which are of non-conserving types.

Other General Observations

Each water works operator should have a rather thorough acquaintance with the extent of drainage areas on streams that could cause flood damage to the water works property he serves. He may find for instance that he should prepare himself against the chance of supply interruption on account of a flash flood on some small stream. He should know the weather bureau or other federal or state agencies concerned with rainfall and flood

APPROVED AIR CONDITIONING
THIS AIR CONDITIONING SYSTEM REQUIRES ONLY A NOMINAL AMOUNT OF WATER FOR OPERATION.
OPERATION HAS, THEREFORE, BEEN APPROVED BY FLOOD EMERGENCY HEADQUARTERS AND IS IN ACCORD WITH THE WATER CONSERVATION PROGRAM.
Melvin P. Hatcher
DIRECTOR OF WATER DEPT.
Permit No.
By

POSTER PERMIT prominently located on premises served by air-conditioning installations having water conserving cooling systems.

prediction reports for areas tributary to streams that might cause flood damage to his property. In the case of the latter reports he should know their general adequacy and the application to the property.

Moreover the water works operator should be acquainted with possible state or federal reimbursement plans. The water works property at Kansas City sustained losses totaling $115,000 in the 1951 flood. Reimbursement from the federal government under Public Law 875 totaled only about $15,000. The latter law, which became effective on July 19, 1951, is administered through the states. It provides reimbursement for emergency and temporary repairs. The latter definition excludes inventory losses, as well as repairs made by city forces and any improvements of a permanent nature made to overcome damage from current or future floods.

Each water works operator should understand the extent to which he is required to rely on the authority of the health officer in his area. Kansas City's charter vests supreme authority in such matters in the city's Director of Health. During the 1951 flood it was the latter's responsibility to say whether water was to be boiled and to issue all orders relating to the use of water sterilizing agents. One news release for instance, included the following provision: "Chlorination can be accomplished by adding Chlorox or Hilex or Purex to the water in the proportion of 1 drop to 1 quart and let it stand 30 minutes". The same news release called attention to the fact that Halazone tablets had been made available by the U. S. Public Health Service and would be distributed free by pharmacists.

Valving plans for distribution systems may well provide for the segregation of areas likely to be flooded. In this way it is possible to insure against the loss of large volumes of water through broken mains or services in the flooded area. Many services were broken in Kansas City in 1951 as the result of strains imposed by movement inside of flooded buildings.

In this connection it may be well to call attention here to the usefulness of continuous pressure records at a number of points in the distribution system. Kansas City has 40 recording pressure gauges for 900 miles of mains. These records may be helpful in the location of any substantial losses of water and may be particularly helpful as evidence of conditions prevailing during any emergency.

EMERGENCY ENCLOSURE for motors at River Pumping Station, before welding on end plate. Thereby, motor-pump units could continue in service even with water flooding the pump pit.

Plan for Auxiliary Help at the Supervisory Level

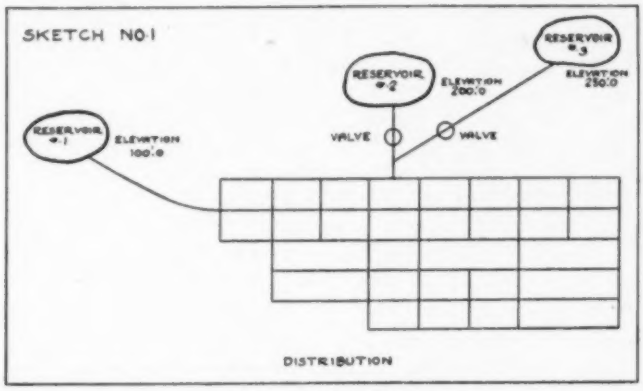
Finally, each operator should be prepared to supplement his permanent forces with such additional help as is needed. He is apt to find a rather ample supply of craftsmen such as machinists, welders, electricians, and of general laborers, all fitting rather readily into any recovery plan that is adequately supervised. The greatest dearth of help is apt though to be in the supervisory field. To the extent that it can be done—and this will vary considerably with communities—the operator's disaster plan should anticipate this need and prepare to meet it. Consulting engineering and equipment companies have the best reservoirs of potential supervisory help. Their usefulness would be improved, however, if they could be briefed on the possible scope of their duties and could be made acquainted with the property before a disaster strikes.

This dearth of supervisory help was keenly felt in our flood operations; and, despite the contribution of excellent help from consulting engineering firms and others it was necessary for the Water Department's supervisory force to work a total of more than 600 hours overtime during the emergency some being on more than 24 hours continuous duty. The work schedule in the last days of the emergency was reduced to something near a 12-hour shift basis but even this was impossible in the first few days of the flood. One supervisor was actually required to remain on duty for 60 hours without relief.

It probably would be helpful to the whole cause of disaster preparedness if the community plans could be made to include an overall advisory committee having sub-committees prepared to deal with specific recovery problems. It is likely in any disaster that the water works operator will be faced with many decisions which will be of such importance to the community that they should not be left to a single person. The sub-committee designated to deal with the operations of the water works property should include considerable engineering talent so as to insure its helpfulness in the emergency.

Application of Altitude Valves and Pressure Regulators

by WILLIAM F. END, *Engineer and Treasurer, Ross Valve Mfg. Co., Troy, N. Y.*



Valves to Balance Head

THE subject matter of this paper is a review of the practical and successful installation and operation of automatic valves—some having been in service (and on 24-hour duty) for a half century.

Along with the development of the science of supplying pure water, has grown the closely allied work of distributing this water to the population being served. As the areas of population have expanded with the evolution of running water at the tap in the household, and the extinction of the public well, so likewise have the problems of pressures and pressure control expanded.

The old adage, "You never miss the water till the well runs dry" was never more true when applied to the present-day water supply. From the standpoint of health, and the danger of fire hazard to a community, even a temporary shut-down of service or pressures in a public water supply is of serious consequence.

The magnitude and responsibilities of the present-day water supply system have necessarily caused water works engineers and operators to turn to the use of automatic devices for increasing the efficiency and reliability of the service. Let there be no mistake about the responsibility of these individuals; theirs is a 24-hour job subject to the mandates of the commission, politicians, and individual consumer. To provide anything but a miserable existence for the operator, it becomes a "must" to have in the system devices such as automatic valves and automatic equipment.

The advantages of an automatic pressure control valve, properly designed, installed and maintained, permit flexibility within the system because of the ability of this device to adjust itself for the normal and abnormal conditions over the 24-hour day; and without undue attention by the operator.

Types of Automatic Valves

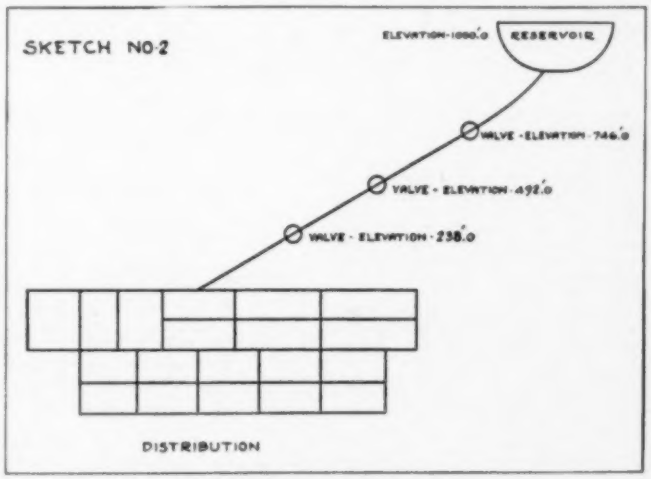
There are four standard types of automatic valves, any one or combination (a single unit having two or more controls) of which may serve in the control of flow or pressures—thereby increasing the efficiency of the complete water supply system. A gravity or pump supply with or without tanks floating on the system undoubtedly will have need for some type of automatic valve which will correct unbalanced or excessively high pressures.

The four basic or standard types of automatic valves may be identified as: 1. Pressure Reducing, 2. Altitude, 3. Relief-Surge-Back Pressure, and 4. Float.

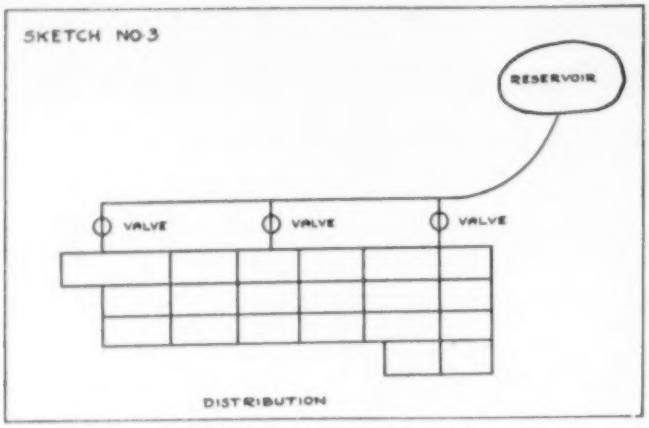
Pressure Reducing Valves

The first of these valves made its appearance in the waterworks field as a throttling orifice in London about 1700. Constant pressure reduction was, of course, possible only with a uniform rate of flow. The engineer soon devised a means of changing automatically the size of orifice (in smaller valves only). This device was in the form of stem movement into and out of the valve seat. While the change was an improvement, the design made use of an unbalanced stem and was considered by qualified students to be bad practice.

As late as the 1870's, pressure reduction in water supply for pipe lines larger than 3" was accomplished by what was known as *break-point basins.* Water discharging from a pipe into these small basins would reenter the pipe at about zero pressure; and, depending on the head or pressure to be dissipated, one or more break-points were a part of the gravity pipe line from reservoir to distribution. By this method of pressure reduction, control for the varying rates of flow was difficult and resulted on the one hand in overflow of the basin with consequent waste of water; and, on the other hand, drainage of the basin and entrained air in the pipe line. The engineer's problem of maintaining adequate flow, pressure reduction and elimination of air and waste was ultimately solved by replacement of



Valves to Reduce Static Pressure



Valves to Balance Unequal Pressure

break-point basins with the pressure reducing valve.

A valve which will maintain constant pressure at its discharge side is considered a *pressure reducing valve*. In the sketches immediately following are illustrations of the use of this valve adapted for the particular need in conduit from reservoir to distribution.

Sketch No. 1 shows reservoirs and a distribution system in which, as the extensions enlarged the system, additional reservoir or storage is required. Since reservoirs normally cannot be located at one elevation, the problem of heads becomes one of the balancing of pressures; and the need, therefore, of automatic devices. Pressure reducing valves in the pipe lines from the reservoirs of higher elevation may be adjusted to discharge into the system at the same head as that available from the low reservoir.

Sketch No. 2 is another illustration showing need of pressure reduction in a pipe from a reservoir having an elevation (let us assume) 1000 ft. above the distribution system. If the static pressure of 1000 ft. (or approximately 435 lbs.) were to enter distribution, with no stretch of imagination one may visualize the problems with which the operator would be confronted. Three stations of pressure reduction from 110 lbs. to 10 lbs. each would dissipate approximately 700 ft. or 300 lbs. of static head; and allow approximately 100 lbs. pressure to safely enter the distribution.

Sketch No. 3. Where, because of the contour of the terrain, a community is inflicted with a distribution which has much greater length than breadth, and a supply entering at one end, the problem of unequal pressures because of head loss is a major one. Assuming the trunk main runs the length of the distribution system, uniform pressure may be had throughout the entire length of the system by supplying water through pressure reduction chambers located at strategic points along the feeder main.

Sketch No. 4. A community located on a side hill, with little or no flat land, presents a problem of pressure zoning; and suggests inter-connection of these zones by pressure reducing valves. When our forefathers chose to settle on the banks of a river in mountainous and semi-mountainous country, they had in mind water transportation and water supply in the form of the hand pump and bucket. Expansion and development was adjacent to the river; however, when expansion (prompted by the river flooding low lands or for other reasons) started movement up hill to higher ground, the settlers promptly engineered the first of our gravity supplies. As the community or city grew upon a side hill, so also grew the problem of constant and uniform pressures, resulting in the development of pressure zoning and the further need of the pressure reducing valve.

Sketch No. 5. In passing, comment should be made on the so-called "sleeping valve." This valve (pressure reducing) located between two systems, zones or districts, opens occasionally only for a pre-adjusted pressure to supply makeup water for the zone on the discharge side of the valve. The valve also may be made to allow a reverse flow if there is need for such provision.

Altitude Valves

The altitude valve, another of the four standard automatic valves, attracted attention and interest when standpipes and elevated tanks were accepted by the waterworks profession as efficient instruments in the operation of the distribution system. The valve increased the value of the tank by effectively controlling the water storage.

Filling a tank on the off-peak load and automatically isolating the tank for use during peak loads is the service which altitude valves contribute to the efficient performance of the tank and, consequently, to the overall efficiency of the system. The use of this valve is not confined to tanks alone, for they are used on open and closed reservoirs in filtration plants, and in aerator basins.

In specifying an altitude valve, one usually calls for a single or double acting valve, amplifying in the specifications a particular feature—depending on the service requirements. If an assembly so specified does not make of the valve a combination valve (an assembly to be treated in subsequent remarks) the valve is classified as a single or double acting altitude valve.

Sketch No. 6. A single acting altitude valve is one which permits flow into the tank or reservoir and closes to prevent overflow. Discharge from tank or reservoir is taken through a separate pipe or a bypass and swing check around the altitude valve.

A single acting valve may have an external control which will allow the stem in the main valve to operate in two positions—wide open and closed—or as a throttling valve where the main stem floats on the column of water, gradually closing as the water rises in the tank or reservoir.

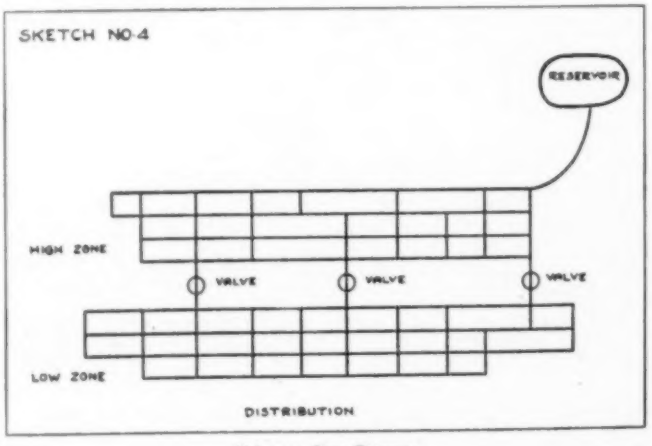
The double acting valve opens wide to pass water into the tank, closes to prevent overflow, and opens wide for reverse flow from tank to distribution. The installation of this valve would therefore require but a single pipe for supply to and discharge from the tank.

The location of an altitude valve should be adjacent to the tank or reservoir, or as near as construction obstacles will allow. Such location will permit communication to the pilot of the true static head of water in the tank, which otherwise is not possible because of friction loss between valve and tank. A true static pressure communication to pilot will guarantee sensitive and accurate control of the tank.

Altitude valves are normally controlled by hydraulic pilots; however, both the single acting and double acting altitude valves may be controlled by a three-port solenoid which is actuated (energized or de-energized) by a float or pressure switch.

Relief or Surge Valves

The relief or surge valve, sometimes called back pressure valve, is another of the four standard types of automatic valves in use in the waterworks field. This valve



Valves to Zone Pressure

responds to pressures at its inlet side rather than to pressures at the discharge side, as is the case of the pressure reduction valve or the single acting altitude valve.

When referred to as a relief valve, it is considered an automatic device for releasing a gradual pressure rise which may, without correction, subject a pipeline to a rupturing pressure. The installation is made where there is easy disposal of the wasted water necessary to dissipate the pressure wave or back-flow surge within the line. The location of the valve may be in a side outlet discharging to a stream, well, or zone of lower pressures.

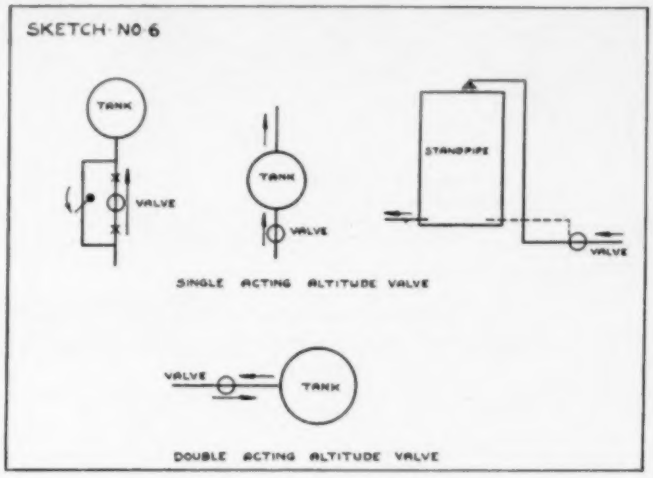
In terms of a surge valve, we think of the valve as an automatic device which will arrest sudden pressure rise—the intensity of which may produce hammer in the pipeline. Installation may be as mentioned above or, where used in conjunction with pumps, in a bypass around swing check and pump to the suction.

As a back pressure valve, we think of an installation where the upstream pressure (not to exceed a predetermined amount) is to be maintained. When performing as a back pressure valve, the valve passes or discharges only that volume of water which will hold the upstream pressure to that desired. This type of service is advantageous in a system of two zones where one (during certain periods of the day) may waste a volume above its requirements to another. The valve will pass only the amount of water limited by the adjustment of the pilot so that the zone receiving this water cannot receive an overdraft through the valve.

A valve of this description (in addition to the use just described) may serve as a protective measure against over-drafting by deep well pump. Also, installed in a service reservoir receiving water from a storage reservoir, the valve may be adjusted to throttle flow; and, at the same time, maintain pressure on aerator nozzles for aeration.

Float Valves

Another of the standard automatic valves is the float valve. This assembly may be specified as direct acting (with float and lever arrangement) or with main valve stem supported by large float (hydraulic pilot operated or solenoid pilot operated). In any case, a float is the prime mover and is directly or indirectly responsible for movement of the stem in main valve.



Single and Double Altitude Valves

As a direct acting valve, the operation is throttling; however, as hydraulic pilot controlled valve, its operation may be throttling or the stem may be made to assume a wide open or closed position. When a solenoid pilot is used in conjunction with a float switch to actuate the main valve, the stem operates in either a wide open or closed position.

In the waterworks field, the float valve is used extensively in warm climates where freezing will not interfere with the movement of the float; however, in colder climates, where the use of the valve is a problem (due to its exposed mechanism) the operator may substitute some form of altitude valve.

Combination Valves

At this point, having covered the four standard assemblies of automatic valves, it would be an oversight if we failed to comment on the combination valve. These have only in recent years been recognized as a further step toward more efficient control of the water supply system—not alone in the light of economy as labor saving devices, but a means of obtaining 24-hour regulation and uninterrupted service.

These valves, a combination of two or more of our four standard automatic valves, may be arranged to control flows or pressure in one or both directions through the valve. Two or more hydraulic pilots or solenoid pilots, or combination of both, may (as conditions require) be a part of the external control. To those of us who have not had experience with a combination valve, it may be advisable to refer to one or two of these valves.

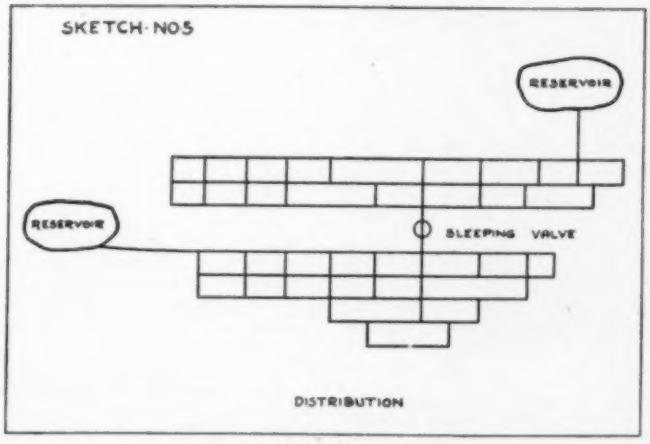
Sketch No. 7. In this sketch, two separate systems are illustrated:

Zone No. 1 with a normal pressure of 80 lbs. and Zone No. 2 with a normal pressure of 50 lbs. The problem assumed is one in which Zone 1 can assist Zone 2 which (during periods of high draft) experiences a lowering of pressures. Other conditions involved are the excessive pressures which Zone 1 may place on Zone 2; and the possible overdrafting of Zone 1, particularly in the event of fire in Zone 2. Also, in the event of fire in Zone 1, priority must be given to Zone 1 for fire flows.

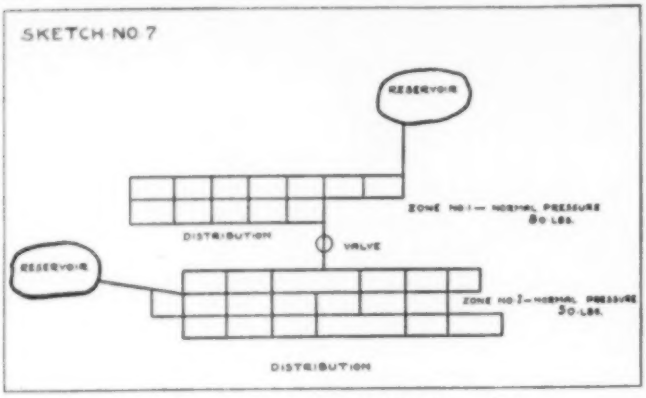
The valve which will meet these requirements is a combination valve having two hydraulic pilots in series—one to control the valve as a pressure reducing valve so that discharge into Zone 2 is held to a predetermined pressure; the other pilot to control as a back pressure valve and insure against overdrafting Zone 1. The valve, therefore, is a combination pressure reducing and back pressure valve.

The predetermined safe pressure for Zone 2 is 60 lbs.—therefore, the pressure reducing pilot has the responsibility of delivering the safe pressure. Obviously, Zone 1 is to have priority; therefore, to avoid overdraft by Zone 2 in event of fire or break in this Zone 2, a predetermined pressure adjustment on the back pressure pilot is to provide the necessary protection. If this adjustment is 45 lbs., and for any reason consumption in Zone 2 is excessive (and the pressure in Zone 1 becomes less than 45 lbs.) the valve closes or throttles.

The following will identify a combination altitude and back pressure valve controlling a tank—operating in conjunction with pumps taking suction from the tank. This valve is to pass water into the tank (how-



Valves to Supply Make-Up Water



Combined Pressure Reducing and Back Pressure Valve

ever for two predetermined back pressures on the distribution), close to prevent overflow; and, when pumps are taking suction, the valve remains closed to prevent circulation thru the valve to tank.

The conditions of operation as planned are such as to require three hydraulic pilots and two solenoid pilots. In performing automatic operations as above, two hydraulic back pressure pilots are in parallel (one in series with electrical solenoid and pumps —the other hydraulic pilot in series with solenoid to be manually operated by a switch located at a remote point). The third hydraulic pilot, for closing to prevent overflow of the tank, is in series with the two parallel hydraulic pilots and their respective solenoids.

In concluding remarks, comment should be made regarding practice which governs the manufacture and installation of automatic valves. The design by a manufacturer or specifications by the engineer must incorporate the factors which will provide for the best service and best installation.

For best service, the following characteristics should be considered: maximum capacity range, sensitivity, long life, and low maintenance cost.

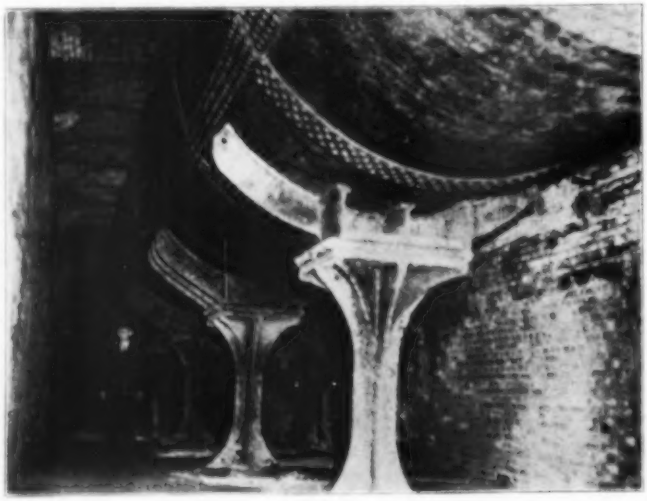
The best installation would predicate correct selection, correct size, battery or single unit, proper valving for isolating the automatic valve, and a valve pit drained and of sufficient size to allow two men on either side of valve to work comfortably while making tests or adjustments.

In conclusion, it can be said that the use of automatic valves has been, is, and will always be essential to the efficient operation of a water works system.

Seattle Voters Defeat Fluoridation Proposal

Seattle's voters on March 11th turned down the proposal to adopt fluoridation of its water supply by almost a two to one vote cast against the proposal. At the same time the voters turned out their 10-year mayor. The vote on fluoridation was surprisingly one sided, with 44,814 for fluoridation and 86,230 against it. During the election campaign the controversy over fluoridation at times overshadowed the hot political fight.

Fluoridation was voted down after having been a lively issue in the press and many town-meeting type debates for a two month period. While the proposal to fluoridate had the support of medical and dental groups, the Parent Teacher's Ass'n and other civic bodies bodies, the opponents, including individual doctors and others were successful in raising widespread doubts in the minds of the public concerning possible long term harmful effects. The opposition termed the proposal "mass medication" and an imposition on individual rights. It was the opinion of astute political observers that the proposal was defeated by that all important "element of doubt" created by physicians campaigning against medicinal treatment of the entire water supply merely for possible benefits to a minority population.



Historic

Before the Civil War in 1860 New York City constructed the famed Croton Aqueduct much of which consists of pipe fabricated from half-inch wrought iron plate. The picture reveals a section of this pipe still in service almost 100 years later and in excellent condition. Note the number of rivets used in this high pressure conduit.

WATER!

The cover picture of this issue has no connection with any article in the issue. It was chosen solely for its beauty and because it symbolizes *WATER—God's greatest gift to man.*

This great color shot of autumn tinted golden maples, edging the Green River with its back-drop of verdant firs, was made in southern Washington by the Northwest's renowned nature photographer, Ray Atkeson of Portland, Ore.

As a matter of interest, this same Green River further down becomes an important source of water supply for the City of Tacoma, Wash.—Ed.

"Hedge"

L. L. Hedgepeth

Becomes Editorial Associate of Water and Sewage Works

WITH great pleasure we announce that L. L. Hedgepeth, widely known Water and Waste Consultant of the Calco Chemical Division of American Cyanamid Company, has accepted our invitation to become an Editorial Associate of *Water and Sewage Works*.

Known to his many friends and admirers as "Hedge," Mr. Hedgepeth is a native Virginian from Chesterfield County, near Richmond, where he was born June 1, 1899. His life history is a Horatio Alger story, since his parents died early, and "Hedge" was thereafter cared for and received his early training and education in the Methodist Orphanage in Richmond, Va. He entered North Carolina State College in 1921 and worked his way through to graduate in 1925 with the degree of B.S. in Chemical Engineering.

Upon graduation "Hedge" joined the firm of Wm. C. Olsen, Hydraulic and Sanitary Engineers of Raleigh, N. C., and operated water purification plants designed by this firm. He also served as chief of the Water Pollution Laboratory and later as District Engineer with the N. C. State Dept. of Health. Amongst the water purification and sewage treatment plants which he operated as Superintendent of Purification were those of Thomasville, Southern Pines and Elizabeth City, N. C. It was while in charge of the latter that he developed the process of chlorinating ferrous sulphate as a practical and economical ferric iron coagulant, successfully employed to remove the high color from the water supply of Elizabeth City. The coagulant became known as "Chlorinated Copperas".

From Elizabeth City, Mr. Hedgepeth in 1929 went to work for the Pennsylvania Salt Mfg. Co. of Philadelphia, as its first Technical Service Engineer in the water, sewage and industrial waste fields. He rose to the position of manager of Technical Service and was Technical Assistant to the Operating Vice President when he resigned in 1947 to accept a newly created position in Virginia's pollution control program for which he was especially well qualified.

From 1947 to 1949 Mr. Hedgepeth established an enviable record for accomplishments as Executive Technical Secretary of the new State Water Control Board of Virginia. Then, "big business" recognized his abilities and qualifications to the extent that he was persuaded to leave Virginia and join the Calco Chemical Div. of American Cyanamid Company as Water and Waste Consultant, which position he has occupied since 1949.

A member of many technical societies and associations, his committee assignments have been many. He has just completed a three year term as a member of the Board of Control of the Federation of Sewage and Industrial Wastes Ass'ns. and continues to serve the Federation as member of its Publication and Program Committee and its Committee on Industrial Wastes. He serves on the Water Supply Comm. of the Am. Public Health Assn. and Committee on Safe Handling of Chemicals of the Am. Water Works Assn. In the Manufacturing Chemists Ass'n. he has served as chairman of the committee on Water Pollution Abatement and as member of several other committees. For several years he contributed importantly to the work of the Chlorine Institute's committees on Chlorine Container Specifications and Safety and Chlorine Container Fusible Plugs. He has served the Compressed Gas Assn. on its Tank Car and Tests and Specification Committees. During World War II, he served the War Production Board as a member of one of its Advisory Committees on Chemicals.

Mr. Hedgepeth has produced numerous papers and articles which have been published in various technical magazines and association journals. Many of these have been published in *Water and Sewage Works*, the most recent of which was his highly complimented article printed in our September 1951 issue under the caption—"Industrial Wastes—A Worm's Eye Viewpoint."

The accomplishments and attainments of our new Editorial Associate have been recognized by the associations in which he has been a leader, as indicated by the following awards and honors in 1944 the George W. Fuller Award of the Am. Water Works Assn.; in 1950 the Arthur S. Bedell Award of the Federation of Sewage Works and Industrial Wastes Assn's. He has also received from the Manufacturing Chemists Assn. its Special Commendation Plaque. The Elder P. D. Gold Medal was awarded him by N.C. State College, denoting "graduate of the year." He also wears the Key of Tau Beta Pi.

All who know our new Editorial Associate are aware of his technical standing and reputation as a tireless worker and accurate reporter. His writings are reputed for their clarity and pointedness. We are fortunate to be able to add his name to our masthead.

Water Treatment by Zeolites —A General View

by M. P. ROBINSON, *Consultant, Water Treating Division, Worthington Pump and Machinery Corp., Harrison, N.J.*

THROUGHOUT industry water constitutes an essential element in a product or in the process of manufacturing a product. All natural waters contain impurities. These impurities consist of dissolved and suspended matter which, more often than not, interfere with the quality or the efficient production of a product.

Suspended impurities are removed by physical filtration, but dissolved impurities, aside from distillation, require chemical methods for their removal. There are two available chemical methods, known as "precipitating" and "zeolite" processes. This article deals with the removal of dissolved impurities from water by the zeolite process.

The dissolved impurities are present as molecules composed of equal numbers of positively and negatively charged atoms or groups of atoms called ions. The positively charged ions are called "cations" and those negatively charged are called "anions."

Zeolite is a solid granular material possessing ion exchange properties and is effective in the removal of objectionable ions from water, the phenomenon being accompanied by their replacement with less objectionable ions imparted by the zeolite. Calcium, magnesium and sodium are the principle impurity cations to be dealt with, and their bicarbonates, sulphates and chlorides are the principal impurity anions. Silica, present as silica dioxide, may also assume importance, notably in boiler feed water application.

Ion exchange properties in naturally occuring material, such as clays of the earth, were previously detected, but at the middle of the nineteenth century H. S. Thompson and J. Thomas Way seem to have presented the first comprehensive description of the phenomenon, together with a method of synthetically producing sodium aluminum silicates which constituted the first commercial zeolites.

The several highly technical widely different theories offered in explanation of ion exchange phenomena related to zeolite have been relatively unimportant to the creditable advance in practical commercial application based largely upon performance data obtained from laboratory and field experiment.

Zeolite Types

The open market offers numerous zeolites under various trade names, but those of outstanding present day interest are processed greensands, Fig. 1, and synthetized resins, Fig. 2.

The greensands, while cheaper, are limited in capacity and their longevity is contingent upon operation at temperatures below 100F and within a narrow pH band, which is to say the limit of acidity or alkalinity of the water being treated.

Resinous zeolites are more costly and higher capacity materials, some of which do not seriously deteriorate when operating over a broad pH range, and a recently developed styrene base resinous material bids fair to withstand temperatures up to 240F.

The selection of a zeolite having the proper exchangeable ion is governed by the character and degree of purification required for a given application. Sodium, hydrogen and hydroxide ions provide the common variety from which selections may be made. The market price of zeolite is roughly proportionate to its capacity. Zeolite is transported in a moist condition and suitable precautions should be taken to prevent freezing.

Capacity

The amount of exchangeable ions present in a zeolite is the measure of its capacity to remove impurity ions from water. While all modern quantitative water treating analyses are expressed in parts per million, it is still strangely customary to express zeolite capacities in grains, one grain per gallon being equivalent to 17.1 ppm.

Capacity ratings are commonly stated in grains per cubic foot of zeolite. Zeolites are available with capacities ranging from 2,800 to 30,000 grains per cubic foot. Plant capacities are stated in thousands of grains or kilograins (kg.).

The required volume of zeolite for a given application is prescribed by its kilograin capacity and the character and amount of water to be treated during the periods between regenerations.

The horizontal cross sectional area of the bed is prescribed by the maximum per minute flow required to accommodate the load demand, the physical character of the zeolite when considered in connection with the maximum or minimum allowable bed depth, friction through the entire softener unit and the practical orientation of suitable available sizes of tank, piping, operating valves and other accessories. These considerations usually result in a flow rating of from 5 to 20 gallons per minute per square foot of cross sectional bed area.

Some application data has been released which designates the maximum flow rating as gallons per minute per cubic foot of bed. This appears to present no basis for orienting the several considerations necessary to the design of a water softener, but does set a flow limitation useful in preventing insufficient contact time between water and zeolite.

Regeneration

In service the supply of exchangeable ions of any zeolite becomes exhausted and must be replaced from time to time. This is generally accomplished by contacting the zeolite with a solution of sodium chloride, sulphuric or hydrochloric acid or sodium hydroxide as the need may be.

The regenerating routine usually consists of three operations. The bed is first backwashed by upward flow to "expand" it or free the grains of zeolite which have become more or less tightly packed by the previous down flow service, and to remove any accumulation of suspended matter. Backwash rates range from 2 to 8 gallons per minute per square foot. Except in

Fig. 1. Grains of greensand zeolite. Approx. 15X magnification. Courtesy of National Aluminate Corp.

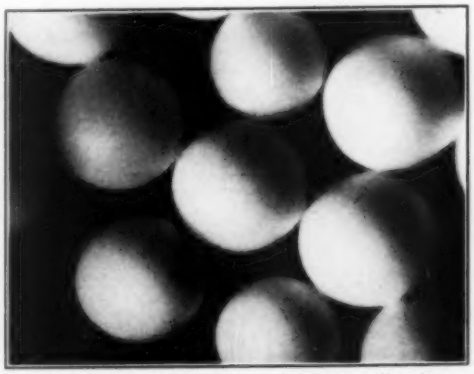


Fig. 2. Grains of a bead or spheroidal resinous zeolite. Approx. 45X magnification. Courtesy of Rohm & Haas.

special cases, the zeolite should not be called upon to fill the dual purpose of filtering and softening. Any suspended impurities which will adhere to the grains or otherwise impede contact should be filtered out before reaching the zeolite.

The next step consists of applying the regenerative solution. Depending upon the strength and kind of regenerant and nature of the zeolite, the time of application varies from 15 to 30 minutes. Most regenerants are stored at maximum strength and applied in such a manner as ultimately to contact the zeolite at strength ranging from 2 to 20 per cent when diluted by the water present in the unit or by motive water if hydraulic eduction is used.

The third step consists of rinsing to waste to free the bed and softener interior of the displaced impurity ions together with all excess regenerant. Since rinsing is a dilution process, an hour's time may be required before the control test of the waste water indicates the softener's fitness for return to service.

The rinsing flow is usually downward through the bed at rates of 1.5 to 3 gallons. Although a number of satisfactory upflow installations have been made, the majority of softeners have been designed for downflow rinse based upon the presumption that better hydraulic distribution, with consequent saving in time and water, is obtained with downflow rinse. One use and replacement of the exchangeable zeolite ions is termed a "cycle of operation."

Guarantees against deterioration in performance capacity and physical stability are usually based upon a specified number of operating cycles.

When operating on the sodium or hydrogen cycle, the raw water, if free from suspended matter, may be used for backwashing and rinsing but the hydroxide cycle representing the last step in deionization requires sodium or hydrogen cycle treated water.

Efficiency

It is inherent in any zeolite that, up to its maximum rating, the higher the rating the greater the regenerative expediture per unit of capacity. In other words, the regenerative process is subject to the law of diminishing returns. If a zeolite with a top rating of 30,000 grains per cubic foot is fully regenerated, 15 lbs. of regenerant per cubic foot may be required, whereas the same zeolite rated at 20,000 grains may require 6 lbs. of regenerant per cubic foot. By the lower rating, two thirds of the maximum capacity is obtained by the expenditure of only two fifths of the regenerant. Hence it is usually better long range economy to invest in more zeolite and operate at less than its maximum capacity. The amount of regenerant used per unit of capacity is termed the "level" of regeneration.

Efficiency also depends in large measure upon the design of the softener with the underdrain system as a major hydraulic component and the means and methods of applying the regenerant running a close second. The dominant requirements of an efficient design are: uniform distribution of flow while treating, backwashing, applying the regenerant and rinsing.

Leakage

Another aspect of efficiency lies in the degree of removal of the dissolved impurities. Such removal is never complete, although complete removal of calcium and magnesium hardness is suggested when the term "zero hardness" is used. From a softening standpoint, the amount of hardness remaining in the softener effluent is termed "leakage." From a deionization of demineralization standpoint, any dissolved matter remaining in the effluent is termed "leakage."

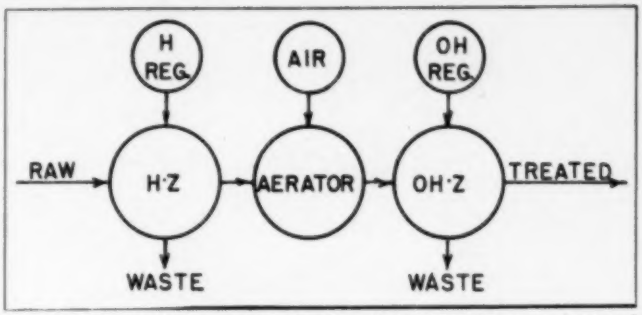


Fig. 3. Deionization. Hydrogen and hydroxide cycles in series with aerator interposed. Sulphuric acid and sodium hydroxide regenerants.

It would be natural to assume that leakage could be prevented if the zeolite bed were made sufficiently deep. However, the exchange reaction reaches a limit beyond which no further reduction of impurities is possible in the same environment. Such single environment reduction is satisfactory for many purposes, but some requirements are more exacting. In the case of series operation of a cation and anion unit the chemical character of the cation effluent undergoes a change when passed through the anion unit. This change of character creates a new environment that enables further reduction when the water is passed through another cation unit. Hence by operation through a series of cation and anion units, the final effluent may closely approach zero dissolved impurity content, but a costly and complicated system may be necessary to achieve the result.

It is common practice to identify zeolites by operating cycle instead of trade name and types. Hence one may say sodium zeolite, hydrogen zeolite or hydroxide zeolite. Sodium and hydrogen are cations and hydroxides are anions, and the zeolite cations trade for the water impurity cations, while the zeolite anions trade for the water impurity anions, therefore zeolites are often referred to by the functional designations of "cation exchanger" or "anion exchanger."

Softener Construction

It has been established that contact between the dissolved impurities and zeolite is most efficiently maintained by passing the water downward through a layer or "bed" of zeolite. Since action is dependent upon contact, the rate of flow and the depth of bed must be correlated to provide the proper time element. So that every portion of the bed will do its share of work, it is necessary that the flow through the bed be uniform.

The maximum depth of bed is prescribed by consideration of friction, capacity and head room, but regardless of other consideration the minimum depth of bed must provide conservative contact insurance and has by common practice been established at 24 inches. Freeboard above the bed ranges from 75 to 100 per cent of bed depth to allow for expansion during backwash.

While open vessels may be used to contain the zeolite beds, the great majority of zeolite plants, include closed tanks or shells suitable for operating on line pressure.

The zeolite bed rests upon a supporting bed of gravel or anthracite from 12 to 15 inches in depth and so graded that the top of the supporting bed will retain the zeolite while the bottom region of the supporting bed will act as a secondary distribution system.

Beneath the supporting bed a primary distribution system is constructed and is usually composed of manifold and lateral piping so designed as to collect treated water or discharge backwash water from openings located on 6 inch centers. In general, the interior of a softener resembles that of the well known sand filter with zeolite replacing the customary sand.

Corrosive conditions inherent in acid cycle operation dictate the provision of corrosion resisting pressure shell linings and corrosion resisting material or lining for pipe, valves and fittings. Rubber lining is extensively used.

Valving for service regenerative routine may consist of a valve nest of individually hand operated valves for controlling the various flows or individual diaphragm valves operating on air or water from a single pilot, or a single valve multiported for all functions may be employed. These "single control valves" or the individual diaphragm valves, may be automatically operated by motor and sequence timer, the sequence being initiated by push button or by a contacting flow meter. The push button and the meter contact arrangements are respectively termed "semi-automatic" and "fully automatic" operations.

Other important accessories consist of rate of flow indicators for observation of the softening, backwash, and rinse rates, slow opening backwash valves to prevent bed distortion by too sudden backwash water inrush, and backwash flow limiting means for prevention of loss of zeolite by excessive subsequent backwash rates.

When the proper ion exchange material is placed in an operating container, usually a pressure vessel, it is termed a "unit" or "exchanger." When an assembly of units together with their regenerative equipment and control accessories are assembled for service, the whole is called a "plant" or "system." The type and size of the units of a system will, of course, vary with the numerous capacity requirements and other conditions of service.

Greensand Zeolites

Greensand is specifically a sodium cycle cation exchange material, the principal source of which is the state of New Jersey.

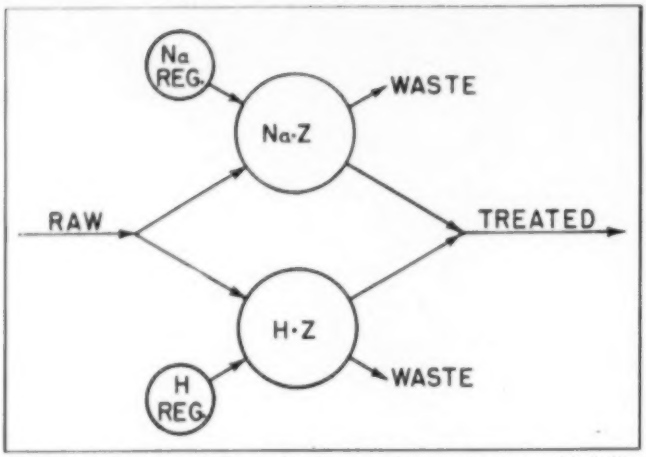


Fig. 4. Split Treatment. Sodium and hydrogen cycles operating in parallel. Sodium chloride and sulphuric acid regenerants.

By exchanging non-hardness sodium ions for the water borne "hardness" or scale forming, soap destroying, calcium and magnesium ions greensand will soften water to a fairly complete degree. Since the other impurity ions are not affected, and the calcium and magnesium are replaced with an equal number of sodium ions, the amount of total dissolved solids in the greensand softener effluent remain essentially the same, as that in the raw water.

A first class greensand zeolite is a rugged material for ratings up to 3,800 grains per cubic foot when operated on a water whose pH remains between 6.5 and 7.5 and whose temperature does not exceed 100F. Greensand weighs about 90 lbs. per cubic foot. Its grain size is usually in the neighborhood of 20 to 60 screen mesh.

As greensand beds are subject to severe packing with resulting friction (which continues to rise throughout the operating cycle) it is usually advisable to hold flow rates below 5 gallons per square foot per min., with the maximum bed depth limited to the neighborhood of 4 feet and the operating cycle below 12 hours.

Greensand efficiency is fair at the expenditure of 0.5 lb. of salt per 1000 grains or hardness removed.

While limitations in greensand application are numerous there is a broad field for its use where only softening is required without regard to any reduction in total dissolved solids.

Resinous Zeolites

A large variety of synthetic resinous zeolites have been produced. For water treating, the greatest interest centers around the "phenolic" and "polystyrene" types of cation and anion zeolites respectively embracing active sulphonic acid and amine groups. The anion zeolites are subdivided into "strong" and "weak" base categories, these designations respectively stemming from their aptitudes for removing weak or strong acids from effluents of cation zeolite units.

The *resinous* cation zeolites may be operated on either the sodium or hydrogen cycles, the hydrogen cycle lending the greater importance due to its use in deionization.

There is a strong tendency to produce all resinous zeolites in spheroidal or "bead" grain form. This form reduces bed friction and allows greater hydraulic latitude. The bead grain size lies between 16 and 50 mesh screen and the zeolite weighs from 40 to 50 lbs. per cubic foot—about half that of greensand. Flow rates up to 20 gal. per sq. ft. per min. may be used and backwash rates from 2 to 15 gal. per sq. ft. per min., depending upon water temperature and bed expansion desired. Capacities per cubic foot stated in terms of calcium carbonate range up to 30,000 grains, depending largely upon the operating cycle and selected regenerating level.

The ion exchange efficiency of resinous zeolite is influenced by a number of considerations whose comprehensive presentation lies beyond the scope of this article.

For the purpose of roughly visualizing regenerant requirements, it may suffice to say that sodium cycle operation may require 0.4 lbs. sodium chloride per 1000 grains of impurities, in terms of calcium carbonate removed; hydrogen cycle 0.5 lbs. sulphuric acid; and caustic cycle 0.3 lbs. of sodium hydroxide.

Hydrogen Cycle Operation

In hydrogen or "acid" cycle operation, first unit Fig. 3, the zeolite's only exchangeable ion is hydrogen. When operating on this cycle the hydrogen not only replaces the calcium and magnesium hardness ions but also the non-hardness sodium ions and converts the carbonate alkalinity to carbonic acid and the silica to silicic acid. As a result, the effluent contains sulphuric acid, hydrocholric acid, carbonic acid, and silicic acid. Though soft and considerably reduced in total dissolved solids, such an acidic water having a pH of 3 or 4, is unfit for use except for certain obscure applications. Hence pH corrective measures are generally employed.

pH Correction By Aeration

The reduction of the carbonic acid is of considerable assistance in elevating the pH value to an acceptable degree. Carbonic acid is readily decomposed by inviting the escape of gaseous carbon dioxide (CO_2). Because the carbon dioxide is very loosely held, it will escape to the atmosphere if the proper environment is provided. An "aerator" or "degasifier" second unit Fig. 3, is commonly employed for the purpose.

The aerator usually consists of a tank-like tower constructed of wood and containing a number of tiers of horizontal slats for breaking the falling water into small particles and a power driven blower for maintaining within the tank an environment of extremely low partial pressure for the ready escape from solution of the carbon dioxide. A well designed aerator may be expected to reduce the carbonic acid to 5 ppm. or less and is inexpensive to operate.

After aeration the remaining acidity of the acid cycle effluent may be neutralized by feeding an alkaline solution, such as caustic soda, in which case thorough mixing is extremely important. The caustic application and mixing is usually accomplished in a basin constructed beneath the aerator. The

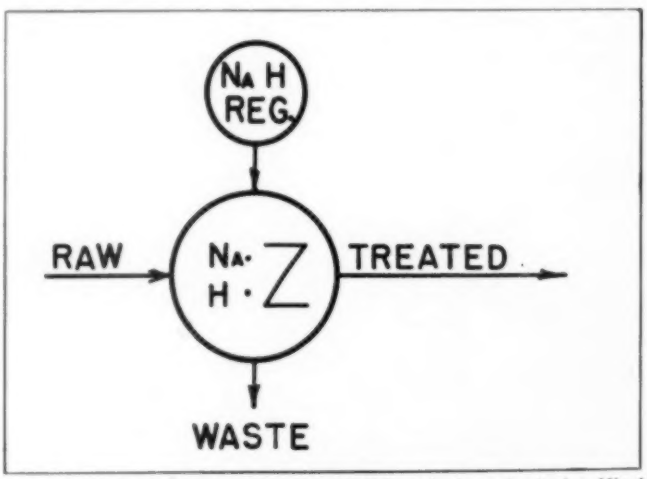


Fig. 5. Mixed hydrogen and sodium cycle. Alkalinity reduction and softening. Mixed sulphuric acid and sodium chloride regenerant.

amount fed is often controlled by a pH meter operating in conjunction with a caustic solution feed valve for automatically maintaining the effluent between prescribed pH limits.

For some applications this method of softening and pH correction fills the need but has the disadvantage of removing no anions such as sulphates and chlorides and adding sodium ions from the caustic soda. In boiler feed water applications the permissible total solids limitations within the boiler may preclude its use.

pH Correction By Split Treatment

Another means of rectifying the pH of the effluent from the hydrogen unit is to treat some fraction of the water with a sodium cycle unit which softens but does not appreciably disturb the original alkalinity of the raw water, and in proper proportion blend this effluent with that of the hydrogen unit, as illustrated in Fig. 4. Thus the alkalinity remaining in the effluent of the sodium cycle unit may be utilized to produce a blend which will have a non-corrosive pH. Here again the pH of the blended water may be automatically controlled by a pH meter operating in conjunction with a proportioning valve mechanism to maintain the correctively proportioned amounts of the two treated waters so that the blended effluent remains between selected pH limits.

With this system the effluent is contaminated with dissolved solids in proportion to the amount of sodium cycle water necessary to neutralize the acidity of the hydrogen unit effluent. Adaptability of the raw water and cost of chemicals and expense of boiler blowdown prescribe a rather narrow field of application for this "split treatment" method.

pH Correction By Mixed Cycle

The split treatment idea suggests that softening and pH control might be accomplished by operation of a cation zeolite on mixed hydrogen and sodium cycle, as shown in Fig. 5. When the ratio of acid to salt content of the regenerant is made to correspond to the ratio of raw water alkalinity to hardness, a soft effluent of controlled pH is possible.

This method is not adaptable to waters of varying character due to the impracticability of varying the regenerant acid to salt ratio in synchronism with varying raw water alkalinity to hardness ratios. It remains to be seen whether or not interest in mixed cycle operation will become more than academic.

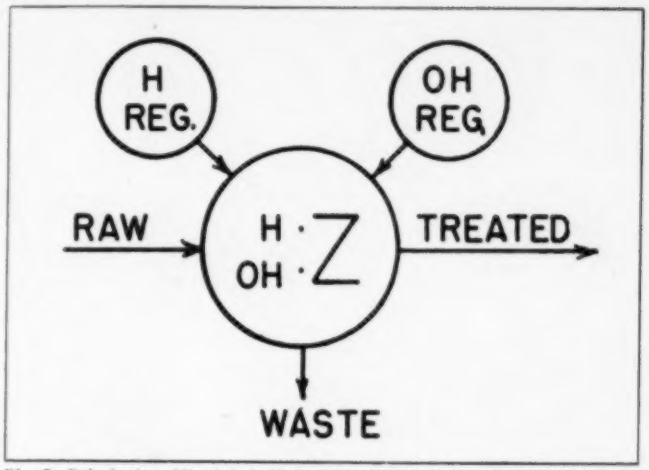


Fig. 7. Deionization. Mixed bed. Hydrogen and hydroxide cycles. Zeolites mixed when operating and separate while regenerating. Sulphuric acid and sodium hydroxide regenerants.

pH Correction By Anion Exchange

Resinous zeolites endowed with anion exchange properties are available for removing both strong and weak acids, thus raising the pH of the hydrogen zeolite effluent without by-product contamination of their own effluents. These are regenerated with sodium carbonate or sodium hydroxide, the hydroxide cycle (see Fig. 3, third unit) being used for illustrative purposes. Economy in regenerant is effected by the use of an aerator ahead of the zeolite for reducing the carbonic acid.

Alkalinity Reduction By Anion Zeolite

The foregoing pH rectification methods have come into being by reason of the general unfitness of acid cycle cation effluents from a low pH standpoint. However, some raw waters contain amounts of alkalinity which make them inferior for certain uses.

Considerable interest has been aroused by suggestion of anion zeolite operation on the chloride cycle illustrated in Fig. 6. The chloride from sodium chloride regenerant exchanges for the bicarbonate and carbonate constituents of alkalinity accompanied by the conversion of the hardness to the chloride form. The hardness, if objectionable, may in turn be removed with cation zeolite operating on the sodium cycle. Sodium chloride is the regenerant common to both zeolites. The softened effluent will contain sodium chloride proportionate to the hardnesses removed.

Deionization

Using several more or less common terms to designate each unit it may be said that when clear water is passed through the hydrogen or acid or proper *cation* unit and thence through the hydroxide or alkali or proper *anion* unit the total dissolved solids in the final effluent may closely approach zero. See Fig. 3.

Such reduction in total dissolved solids has come to be called "deionization" or "demineralization." The cost of deionization depends upon the amount and nature of dissolved solids contained in the raw water and in many cases competes with distillation.

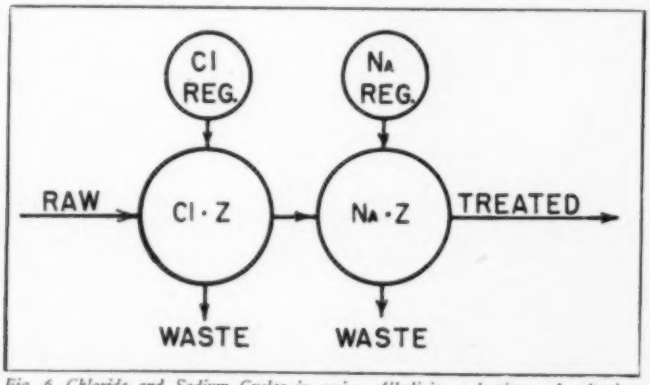


Fig. 6. Chloride and Sodium Cycles in series. Alkalinity reduction and softening. Sodium chloride regenerant.

Mixed or "Monobed" Deionization

Under the subject of "leakage" the necessity for repeated environment changes to enable close approach to zero dissolved solids was pointed out.

Since the environment changes can be induced by series contact of the cation and anion exchange beds, a similar phenomenon will occur if the cation and anion materials are mixed together so that the environment changes are induced by the contact of the water with alternate adjacent grains, instead of alternate beds contained in separate units.

To operate such a "monobed" or "mixed bed" unit, the cation and anion materials must be regenerated with incompatible acid and alkali reagents as shown in Fig. 7. Therefore, it is necessary to separate the two zeolites for purpose of regeneration and thoroughly remix them for the next operating cycle.

The separation is readily accomplished by backwashing or hydraulic grading which is made possible by the difference in settling

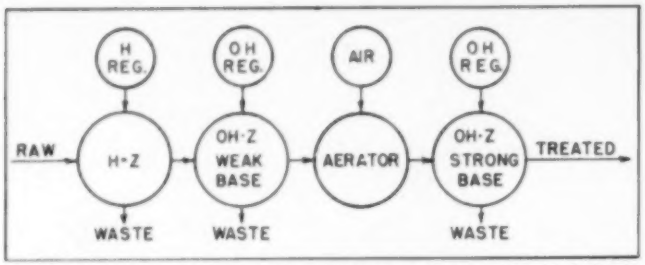


Fig. 8. Silica removal and deionization. Hydrogen cycle in series with hydroxide cycle using weak and strong base zeolites and aerator. Sulphuric acid and sodium hydroxide regenerants.

character of the two zeolites. After separation, the regenerants are passed through their respective bed regions by distribution piping systems designed to induce the flow of the acid regenerant through the cation region and the alkali regenerant through the anion region.

While such necessary construction presents complications, the main difficulty is presented by the necessity for *thoroughly* remixing the materials. Such mixing requires objectionable periods of time. The principle of hydraulic grading so convenient to separation of the materials renders hydraulic mixing difficult and the problem is accentuated by restrictions in the use of high velocity jets or mechanical means which might cause physical wear or disintegration of the zeolite. Therefore, progress in mixed bed development has been limited to relatively small units.

Silica Reduction By Deionization

In addition to silica's contribution to hard scale, vaporization of silica with consequent carryover in the steam has been definitely established for boiler operation above 600 psig. Also silica may be carried over dissolved in the water of wet steam at any pressure. Such silica vapor carryover results in turbine blade deposit and erosion, as pressure reduction through the stages induces transformation of the silica to its solid form. In the case of wet steam carryover, similar troubles begin as soon as the steam is dried in the superheater. Silica reduction is therefore important in boiler feed practice, the required degree of reduction being indicated largely by operating pressure.

Silica may be reduced or practically eliminated by deionization. While there are some exceptions for raw waters of particular character, the most conservative and economic system would seem to consist of a cation unit operating on the hydrogen cycle followed by weak and strong base anion units operating on the caustic cycle for removal of the strong and weak acids, including silicic acid, inherent in the cation effluent. An aerator is usually utilized ahead of the strong base anion unit to reduce the carbonic acid and, to that extent, lighten the load on the strong base anion unit.

A field report on one such system of the type illustrated in Fig. 8 indicates economic silica reduction to range from 5 ppm. to 0.2 ppm.

CONTROL TESTS

Hardness—By Soap Test

For routine operating control testing for hardness the soap test is extensively used. This test involves the observation of the amount of standardized soap solution destroyed by the calcium and magnesium in a measured sample of water. The end point of the test is the formation, by shaking, of a permanent lather on the bottled sample. This test is accurate within three parts per million of the actual amount of calcium and magnesium present.

Hardness—By Versenate Method

A more rapid and accurate hardness test, involving a pronounced color change end point and known as the versenate method, is rapidly gaining popularity. This test involves titration of a measured sample of water with standard versenate solution. When a proper color indicator is applied, the sample turns red in the presence of active calcium and magnesium ions and turns blue when these ions are sequestered or rendered inactive by the versenate. Field accuracies within 2 ppm. are possible with this method; and with certain modifications more suitable to the laboratory, accuracies to 0.1 ppm. are claimed.

Dissolved Solids

The relationship between ionizable dissolved solids and electrical resistance provides a convenient basis for determining the ionizable dissolved solids present in deionized effluents. Generally speaking, the purer the water the greater the resistance.

A meter for indicating resistance employs a Wheatstone bridge and detector cell with electrode plates arranged to indicate the resistance through one cubic centimeter of the water at a specified temperature. The instrument is commonly called a "conductivity" meter and may be calibrated either in ohms resistance or "micromhos" of "specific conductance." The micromho is one millionth of the reciprocal of the ohm.

The resistance of water after 28 distillations is approximately 20,000,000 ohms or 0.05 micromhos or 0.025 ppm. ionizable dissolved solids; and after only one distillation, approximately 500,000 ohms, 2 micromhos, or 1 ppm. ionizable solids.

Realistic values encountered in practical operation of deionizing plants will range from 50,000 ohms, 20 micromhos, or 10 ppm. ionizable solids to 1,000,000 ohms, 1 micromho, or 0.5 ppm. ionizable solids.

The conductivity meter is insensitive to silica which does not ionize. Therefore silica must be determined by other means.

Silica

For fine determinations of dissolved silica, a photoelectric colorimeter offers a convenient and accurate means. The instrument employs a light source and a photoelectric cell to indicate the color density of the water sample colored by ammonium molybdate, the density being directly proportional to the amount of silica present. A less accurate though much less expensive instrument operates on optical color density comparison of a colored sample with color standards.

Carbon Dioxide (CO_2)

A sample containing phenolphthlein will remain clear in the presence of CO_2 either free or combined in the bicarbonate form, but will show pink color in the presence of any normal carbonate. Therefore, the amount of free CO_2 may be measured by the amount of known strength sodium carbonate solution used to combine with all the CO_2 in the formation of sodium bicarbonate. The end point of the test is indicated by the appearance of the pink color as soon as any excess sodium carbonate presents itself in the sample.

pH Determinations

pH is defined as the logarithm of the reciprocal of the hydrogen ion concentration. A litre of pure water contains 0.0000001 gram equivalents of ionized hydrogen (acid) and the same number of hydroxyl (alkali) ions. This number may be written 1×10^{-7} or simply 7 which is neutrality on the accepted pH scale which extends from 1 to 14. If, in water, the ionizable hydrogen ions are in excess of the hydroxyl ions the scale reading will be below 7. If the ionizable hydroxyl ions are in excess of the hydrogen ions, the reading will be above 7. The pH value of a solution is commonly determined by either the electrometric method or the colorimetric method.

Electrometric pH Method

Precision instruments are available for this method. These are usually called pH meters. A pH meter operates on the principle that the electrical potential between a water sample and a constant pH solution contained in an immersed glass bulb electrode is proportionate to the concentration of ionized hydrogen in the sample. A second immersed electrode of constant potential and insensitive to the concentration of ionized hydrogen is employed to complete the circuit through a potentiometer. The electronic character of the modern instrument permits potential indication without appreciable current drain from any element of the system. A third immersed electrode is used for temperature correction.

Colorimetric pH Method

Colorimetric comparators are relatively inexpensive and reasonably accurate devices for pH determinations, and are quite extensively used. Operation of a comparator is based upon the use of a variety of indicators. Indicators are substances which, when added to water, assume a characteristic color corresponding to the pH. The color developed is compared with that of standards. Some comparators utilize liquid standards, and others colored glass standards.

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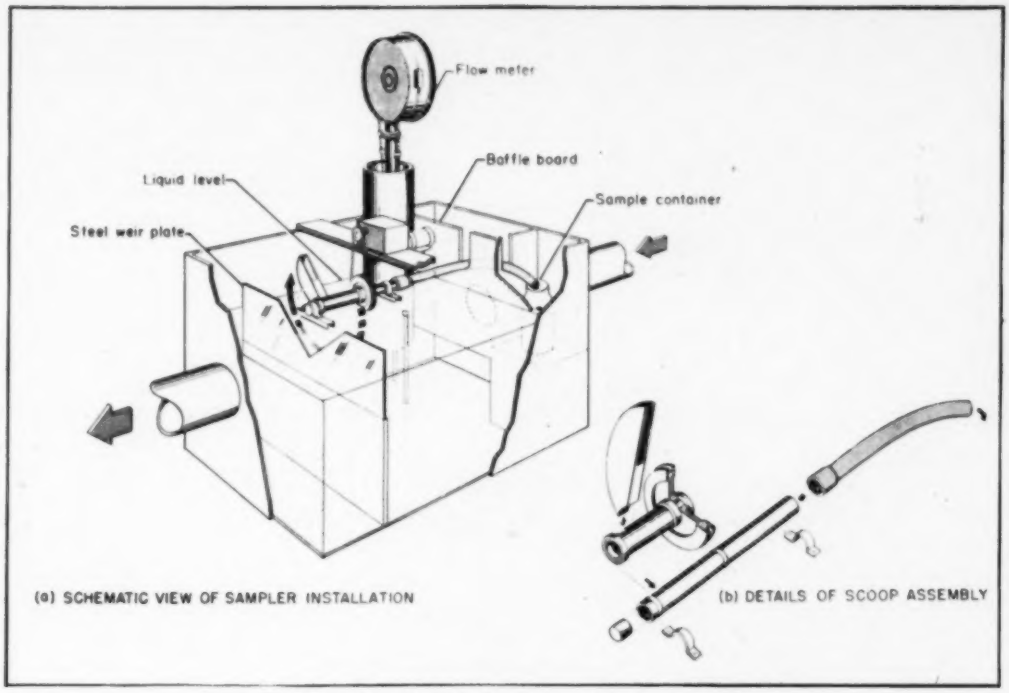

FIG. 1—The "scoop" sampler installation and details of assembly

An Automatic Waste Sampler

Design and Construction Details of an Accurate "Scoop" Type Sampling Device

by

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IN planning a recent industrial waste survey, the development of special equipment was required for sampling the waste. The waste was a soluble type, having very little suspended material and floating oils. A wide variation in the rate of flow and the physical and chemical composition of the waste was expected. It was, therefore, considered necessary to obtain frequent samples automatically and in proportion to the instantaneous rate of flow. The only point available for sampling was in an 8-inch sewer leaving the plant.

The authors reviewed the available literature on sampling equipment. Use of a weir with a rotating "scoop" type sampler as described by Trebler was selected as the method best suited to the requirements. However, only general descriptive information of such sampling equipment was given in the literature.

It is the purpose of this article to present the basic information needed to plan and construct an automatic sampler of this general type to meet specific requirements.

General Description of Sampler

The equipment as constructed consisted of a wooden box in which were mounted a 90° V-notch steel weir plate and a rotating element which, every two minutes, "scooped" a sample of the waste ahead of the weir. The entire assembly was built as a unit and set in place in a break made in the plant sewer line. A water-tight section was provided in the box to hold a container into which the sample increments were discharged and collected.

A float operated depth recorder was set up in the box. This was used in conjunction with the sampler for obtaining a continuous 24-hour record of the waste flows. A schematic drawing of the complete installation and details of the "scoop" element are shown in Fig. 1.

The selection of the weir plate was based on conventional practice. The maximum rate of flow expected was about 267,000 GPD. A 90° V-notch weir 9 inches high was used. Based on an estimated average 24-hour flow of 200,000 gallons, the sampler was designed to yield 10 gallons of sample. Actually the average 24-hour flow turned out to be 340,000 GPD, resulting in slightly over 15 gallons of sample each 24 hours. Although this was more sample than was needed or desired, it does indicate the accuracy of the sampler.

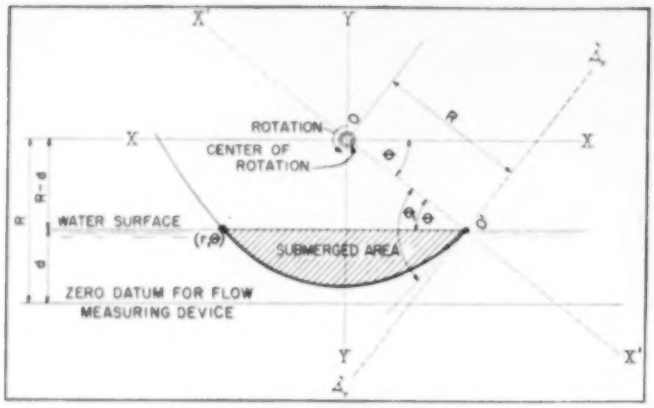

FIG. 2—SYMBOLS employed in deriving formulae

Design of the "Scoop"

The determination of the exact shape of the "scoop" element of the sampler is extremely important, as the shape determines the accuracy of the device. Therefore, a complete development of the derivation of the formula used will be given.

Two assumptions are made: (1) the volume of each individual sample withdrawn by the "scoop" shall vary as d^n, where "d" is the head of water over the flow measuring element and "n" an exponent dependent on the type of measuring element used; and (2) the volume of the individual sample withdrawn is the submerged volume of the "scoop" just as the extreme tip moving upward breaks the water surface. The flow measuring element may be any type of weir, orifice, flume, or other device suitable for the measurement of liquids flowing under open channel or gravity flow conditions.

The following symbols are used in the derivation and are illustrated in Fig. 2.

O = Center of rotation of "scoop," and origin of axes X, Y.

O' = Origin of transformed axes X', Y'.

r, σ = Polar coordinates of any point on curve, using O' as origin.

R = Radius, and distance from center of rotation of "scoop" to zero datum of flow measuring device.

d = Head of water over measuring device, measured above zero datum.

A = Area of submerged portion of "scoop" just as the extreme tip breaks the water surface $= \frac{1}{2}\int r^2 d\sigma$.

t = Inside thickness of "scoop".

V = Volume of sample withdrawn which equals A × t.

The derivation is as follows:

a) Using the transformed axes with origin at O', the equation of the curve is

$r = f(\sigma)$. *Equation (1)*

b) The volume of sample withdrawn for any water depth d is

$V = t/2 \int_{\sigma_0}^{\sigma} f^2(\sigma)\, d\sigma$. *Equation (2a)*

where σ_0 is the angle coordinate at the tip of the "scoop" when $r = 0$.

By assumption $V \propto d^n$, which may be written as

$V = k \left[\frac{d}{R}\right]^n$ *Equation (2b)*

where (d/R) is substituted for d, with R being constant for any given sampler.

c) From Figure 2,

$\frac{R-d}{R} = \sin\sigma$ *Equation (3)*

So that

$V = k\,(1-\sin\sigma)^n$ *Equation (4)*

d) Equating equations 2a and 4

$V = k\,(1-\sin\sigma)^n = t/2 \int_{\sigma_0}^{\sigma} f^2(\sigma)\, d\sigma$ *Equation (5a)*

and by differentiation

$nk\,(1-\sin\sigma)^{n-1}\cos\sigma = t/2\, f^2(\sigma)$ *Equation (5b)*

or

$f(\sigma) = \left[\frac{2nk}{t}(1-\sin\sigma)^{n-1}\cos\sigma\right]^{\frac{1}{2}}$ *Equation (5c)*

e) Since $r = f(\sigma)$

$r = \left[\frac{2nk}{t}(1-\sin\sigma)^{n-1}\cos\sigma\right]^{\frac{1}{2}}$ *Equation (5d)*

when $r = 0$, $\sigma = \pi/2$; therefore $\sigma_0 = \pi/2$ or 90°

f) If it is desired to withdraw a volume of sample V_1 for a given flow Q_1 having a depth of flow d_1 the following relationships are established:

$V_1 = k\left[\frac{d_1}{R}\right]^n$ *Equation (6a)*

$k = V_1\left[\frac{R}{d_1}\right]^n$ *Equation (6b)*

and

$r = \left[\frac{2nV_1}{t}\left[\frac{R}{d_1}\right]^n (1-\sin\sigma)^{n-1}\cos\sigma\right]^{\frac{1}{2}}$ *Equation (6c)*

The formulae as developed can be used for any gravity flow measuring device where the relation of $Q = Kd^n$ exists. Shown in Table I are values of "n" for several of the more common types that might be of general application.

The value of R is determined by adding 3 to 6 inches to the maximum water depth, d, expected. This freeboard is required to provide sufficient clearance to drain the sample from the "scoop" by gravity to the sample container.

Use of Formula

To demonstrate the use of the formulae, the actual design used by the authors will be given as an example.

The following expected conditions were assumed:

a) Average 24-hour waste flow, 200,000 GPD

b) Maximum instantaneous waste flow, 267,000 GPD

c) Inside width of "scoop" (selected arbitrarily), ¾ inch
(If excessive suspended solids will be encountered, this distance should be increased to avoid clogging.)

d) A 90° V-notch weir to be used for control and flow measurement. This established the exponent $n = 2.47$

e) A total of 10 gallons of sample desired for each 24-hour period.

From this basic information, it was determined that the depth of flow over the weir, d, at average flow would be 5.14 inches, and 5.78 inches at max-

Table I

VALUES OF EXPONENT "n"
FOR SEVERAL GRAVITY FLOW MEASURING DEVICES
WHERE RELATION $Q = Kd^n$ APPLIES

Type of Device	*Formula (Q =)	Exponent "n"
90° V notch weir	$Q = 2.52\, d^{2.47}$	2.47
Rectangular weir	$Q = 3.33\, Ld^{1.5}$	1.50
Cipolletti weir	$Q = 3.2\, Ld^{1.5}$	1.50
Parshall Flume (3" throat)	$Q = 0.992\, d^{1.547}$	1.547
Parshall Flume (6" throat)	$Q = 2.06\, d^{1.58}$	1.58

*Q = Flow in c.f.s.
d = Measured head in ft.
L = Length of weir in ft.

imum flow. R was, therefore, set at 9 inches.

The sampler was designed to withdraw a sample every 2 minutes, or a total of 720 samples each 24 hours. For a total of 10 gallons of sample, this would require 0.0139 gallons for each withdrawal, or 3.21 cubic inches. Hence, from Eq. 6b:

$$k = 3.21 \left[\frac{9}{5.14} \right]^{2.47} = 12.9 \text{ cu. in.}$$

From Equation 5d the coordinates were computed as shown in Table II. These points, plotted on polar coordinate paper, give the shape of the "scoop," as illustrated in Fig. 3.

Referring to Eq. 6c, it is evident that when $\sigma = \pi/2$ r = 0, and when $\sigma = 0$, $r = \left[\frac{2nV_1}{t} \left[\frac{R}{d_1} \right]^n \right]^{1/2}$

In general, when $\sigma = 0$, r will not equal R, so that the curve will not pass through the center of rotation 0. Therefore, it is convenient to stop the theoretical curve at a value σ_m corresponding to the "scoop" submergence at the maximum expected flow. From this point on, the curve is fitted arbitrarily to meet the central shaft through which the sample flows to the container. This point is shown in Figure 3 for $\sigma_m = 20°$.

At this point the volume of sample withdrawn would be 4.58 cubic inches using Eq. 4. This corresponds to a flow rate of 285,000 GPD over the weir at a depth of 5.91 inches. Since this is greater than the expected maximum rate of flow of 267,000 GPD, the theoretical curve can be terminated at this point satisfactorily.

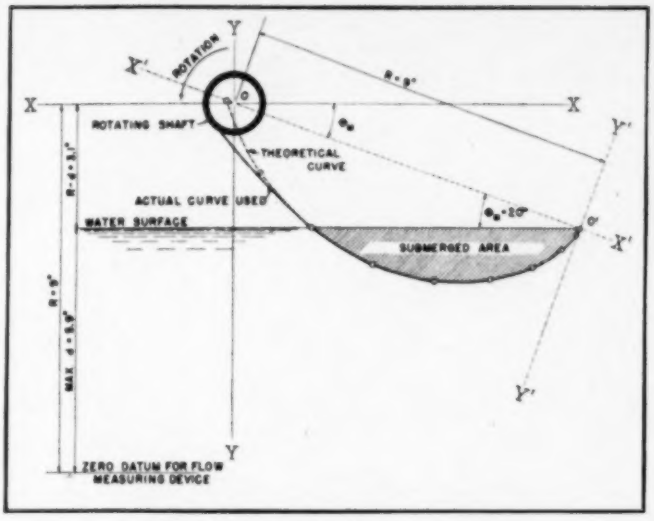

FIG. 3—SHAPE of "scoop" obtained by computation

Precautions in Use of Sampler

In the design and use of a sampler as described herein, the following conditions apply:

1. The waste to be sampled must be flowing under open channel or gravity flow conditions.
2. The measuring or flow control device must be of a type such that the rate of flow is a function of the depth of flow, or $Q \propto d^n$.
3. The waste should preferably be low in suspended solids and oils. Unless the waste is well mixed at the point of sampling, this type of material will tend to stratify. The sampler will then not necessarily remove these materials in the proper proportion for accurate composite samples. This is particularly true in the case of weirs where the velocity would be extremely low at the point of sampling. This difficulty may sometimes be overcome by the use of a mixing device ahead of the weir.
4. The sampling point must be sufficiently accessible to permit installation of the equipment.

Table II

COMPUTATIONS FOR DETERMINING SHAPE OF "SCOOP"

$$r = \left[\frac{2nk}{t} (1-\sin\sigma)^{n-1} \cos\sigma \right]^{1/2}$$

σ	$\sin\sigma$	$1-\sin\sigma$	$(1-\sin\sigma)^{1.47}$	$\cos\sigma$	$\frac{2nk}{t}$	Cols. (4)x(5)x(6)	$r = [\text{Col. (7)}]^{1/2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
0°	0.000	1.000	1.000	1.000	84.9	84.9	9.20
10°	0.174	0.826	0.755	0.985	84.9	63.1	7.94
20°	0.342	0.657	0.539	0.940	84.9	43.0	6.56
30°	0.500	0.500	0.361	0.866	84.9	26.6	5.16
40°	0.643	0.357	0.220	0.766	84.9	14.3	3.78
50°	0.766	0.234	0.118	0.643	84.9	6.43	2.54
60°	0.866	0.134	0.052	0.500	84.9	2.21	1.49
70°	0.940	0.060	0.016	0.342	84.9	0.464	0.681
80°	0.985	0.015	0.002	0.174	84.9	0.031	0.176
90°	1.000	0.000	0.000	0.000	84.9	0.00	0.00

Acknowledgments

The authors wish to acknowledge the assistance given by Dr. J. C. Bell and Mr. W. F. Scharenberg, Jr. of Battelle Memorial Institute in the design and construction of the sampler.

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California Pollution Control Board Publishes Digest of Calif. Enabling Acts

The State Water Pollution Control Board of California, has had prepared and printed a new booklet titled "Digest of Sewerage Enabling Acts of the State of California."

The salient features of 13 acts relating to the formation of basic organizations to construct, maintain, operate and finance sewerage facilities are summarized in this booklet. Also summarized are 12 acts that provide procedures for financing and constructing sewerage works. Three State and two Federal acts pertaining to grants or loans for financing community sewerage facilities are included in summary form.

The digest is intended primarily to aid individuals and communities in studying and solving their local sanitation problems by providing a convenient reference to the enabling legislation in the state of California.

Single copies of the digest may be obtained from the State Water Control Board, Sacramento, or from any of the several regional water pollution control boards without charge.

Often well-timed silence has more eloquence than speech.

Chart for Determining Pounds, Gallons & Cubic Feet of Oils*

Because of the considerable variation in the weight of oils, confusion often exists as to the number of pounds of the different kinds of oil in a given container. It is desirable to know the weight of oil because heat values are almost invariably given in Btu. per pound.

For that reason, this chart was developed. It will be found useful for quickly determining the weight of any number of cubic feet or number of gallons of any of the common oils in daily use; high grade or ordinary gasoline, kerosene, diesel engine oil, fuel oil, and lubricating oil. For example, what is the weight of 20 cubic feet of diesel engine oil?

The dotted line drawn across the chart shows how the problem is solved. Connect the 20 in column A with the point in column D corresponding with "diesel engine oil," and the intersection with column C gives the weight as about 1060 pounds. If the quantity of oil is given in gallons, use column B instead of column A.

Inversely, if the number of pounds is known and the kind of oil is known, a line through the known points gives us an intersection in columns A-B which tells the desired volume.

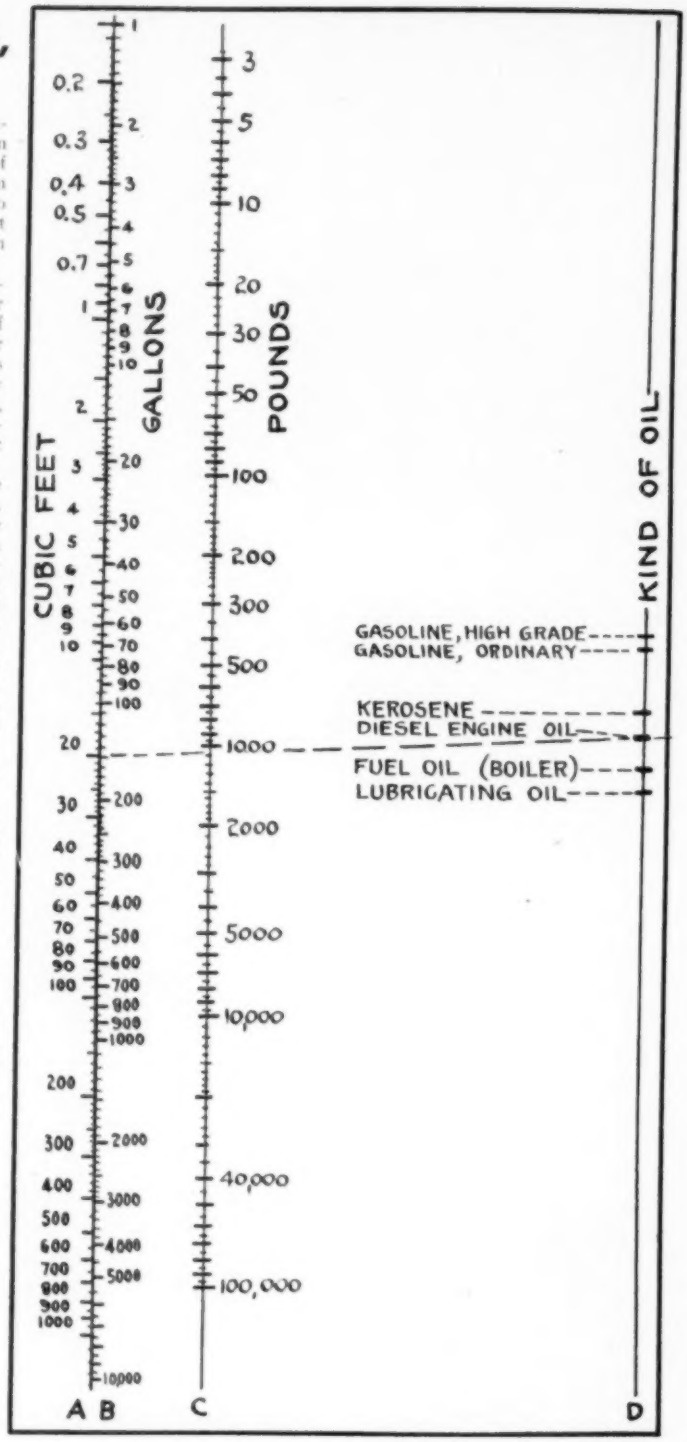
Columns A-B possess further important values as a "conversion scale." Thus for example 20 cu. ft. is equivalent to almost 150 gallons. Or, 1000 cu. ft. is equivalent to about 7500 gallons. And so on.

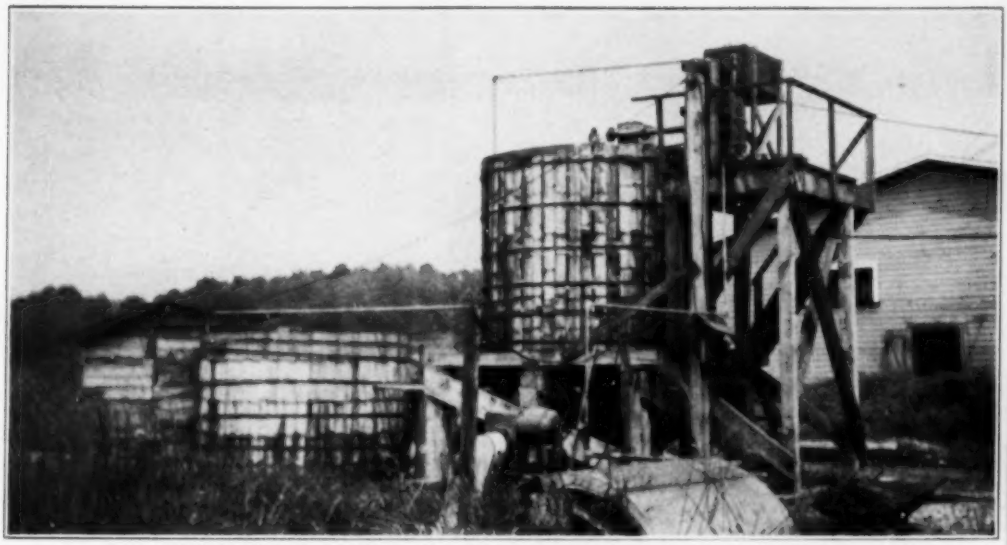
The range of the chart is great enough to take care of most problems. The weight, as will be noted, covers all quantities between three and 100,000 pounds. Should quantities be less, or more, they, too, can be computed by simply shifting the decimal point. Thus for instance the dotted line drawn acros the chart through the 20 cu. ft. can also tell us that 20,000 cu. ft. will weigh 1,060,000 pounds. Merly add three ciphers to the figures in column C because three ciphers were added to the 20. That's all there is to it.

In the event that you should prefer to make computations in longhand or on a slide rule, this chart is based on the following weights per gallon:

	lb./gal.
Gasoline, high grade	6.00
Gasoline, ordinary	6.12
Kerosene	6.81
Diesel engine oil	7.09
Fuel oil	7.50
Lubricating oil	7.78

*Contributed by W. F. Schaphorst, M.E., Newark, N. J.





GENERAL VIEW of pilot plant. Recycle pump house, settling basin, and trickling filter.

Biological Filtration of Kraut and Pickle Wastes*

Pilot Studies of Filter Design and Operation— Results May Apply to Treatment of Other Organic Acid Wastes

by T. R. HASELTINE, *Partner, The Chester Engineers, Pittsburgh, Pa.*

ALTHOUGH neither sauerkraut nor pickle wastes are commonly encountered, it is believed that the results of studies reported on pilot plant biological filtration of those wastes may be of value in the design or operation of biological filters for other organic acid wastes as well. The studies were conducted at the Springboro cannery of the Albro Packing Company and extended over a continuous period of 109 days. The writer is indebted to that Company for permission to present the results.

Character of Wastes

Both pickle and kraut preparation are batch processes and so the resulting wastes are highly variable. At the Albro plant, pickles are packed 5 days per week the year around. Kraut is packed an average of 3 days per week for 30 weeks per year; however, during some weeks none may be packed at all while during others it may be packed daily. Table I presents typical analyses of each type of waste. On any particular day the volume might vary as much as fifty per cent and the chlorides, acidity, or B.O.D. concentration might vary even more. However, the pH of the wastes never exceeded 4.4; at times it was as low as 3.5.

In addition to these day time wastes there was a night flow of cleanup wastes of lesser volume and chloride content, although its pH and acidity were as high as that of the day time flow and its B.O.D. was well over a 1,000 p.p.m.

Description and Operation of Pilot Plant

The State requested treatment to yield at least an 85 per cent reduction in B.O.D. Chemical precipitation could not be depended upon for better than 65 to 70 per cent, but biological filters have successfully treated less acid cannery wastes. Pilot plant studies at Albro were undertaken to determine whether or not the high acidity and chloride content of the wastes would inhibit biological action. The plant consisted of a 10 foot diameter by 6 foot deep filter, a conical bottomed settling tank 10 feet in diameter by 3 foot 6 inches side water depth, a recycle pump for returning settled effluent, and orifice boxes for regulating the flow of both raw waste and recycle. The filter was dosed by a Yeoman's "waterwheel" distributor. Filter media was blast furnace slag 2½ inch to 4 inch in size.

Operation was a compromise between that which would be most desirable for a research problem and that which might normally be expected at a small industrial plant. The Company furnished one full time non-technical operator. The writer's firm made two to three visits each week to direct his work and transport samples, collected by him, back to our laboratory for analysis. No attempt was made to vary the inflow of raw waste in

*This paper, released for publication in Water & Sewage Works, was presented before the Sanitary Engineering Division of the A.S.C.E.

TYPICAL ANALYSES OF THE TWO TYPES OF WASTE

TABLE I

TYPICAL CHARACTERISTICS OF ALBRO PACKING CO. WASTES AFTER SCREENING

	DAYS WHEN ONLY PICKLES WERE PACKED	DAYS WHEN BOTH PICKLES & KRAUT WERE PACKED
Flow, Gallons per 10 min.	20 420	28 500
pH	4.0	3.9
P Acidity as $CaSO_4$ ppm	1100	1100
Chlorides ppm	6500	4600
Total Solids ppm	15 600	12 000
Suspended Solids ppm	200	210
5 Day B.O.D. ppm	2000	2400

proportion to the rate of total cannery discharge. Originally it was intended to apply raw wastes at a predetermined uniform rate for 9 hours per day and to simply recirculate final effluent the remainder of the time. However, it was found that leakage from the system during the night caused the recycle pump to run dry. Therefore, during the first 84 days of operation city water was fed into the system during nights and weekends at the same rate as the raw wastes were fed during the 9 hour day. During the last 25 days raw wastes were fed continuously throughout the 24 hours.

Since samples were only collected over the 9 hour day, all data has been presented on that basis, but care has been taken to distinguish between the two periods. Despite the fact that the actual, 24 hour raw waste B.O.D., loadings were possibly twice as great during the latter period, the accompanying exhibits show little significant difference between the two when they are compared on the 9 hour basis.

A biological film developed on the stone very rapidly. The first samples of influent and effluent were collected after the filter had been in service only 9 days. A total of 32 daily composite samples were collected over the succeeding 100 days. In order to mask the effect of filter recovery that probably occurred over weekends no samples were collected on Mondays. Of the 32 sampling days, 11 were on Tuesdays, 6 on Wednesdays, 10 on Thursdays and 5 on Fridays. (Table II, presenting the results of those analyses in detail, is not reproduced.) During that time raw waste loadings ranged from 575 to 6,800 pounds of B.O.D. per acre foot per 9 hour day. Dosing rates ranged from 9 to 30 M.G.A.D. and recycle ratios ranged from 3.30 to 19.0. (Table III, presenting these data, is not reproduced.) Although dosing rates and recycle ratios were subject to control, the wide fluctuations in B.O.D. of the cannery wastes made it impossible to vary loadings in accordance with any regular pattern. Therefore, the results obtained on each of the 32 sampling days have been plotted as individual points on the following graphs.

Discussion of Plant Performance

In studying the performance of trickling filters, graphs are frequently prepared by plotting the B.O.D. removed against that applied. The applied B.O.D. may, or may not, include that of the recycle. Almost invariably, in the case of sanitary sewage, the points on such a graph fall along, or close to, a straight line, thus indicating a constant percentage reduction in B.O.D. over a wide range in B.O.D. loadings. If the loading is based on applied sewage only, the percentage reduction is frequently about 80 per cent. If the loading is based on applied sewage plus recycle, the percentage is lower. Fig. 1 and 2 are similar graphs prepared from the Albro data. In the first figure the loading is based on raw waste plus recycle, while in the second figure it is based on raw waste alone. It will be noted that in both graphs the points are widely scattered, however, some of them tend to fall along lines of 53 per cent B.O.D. reduction based on total applied load, or 90 per cent reduction based on the B.O.D. of the raw wastes alone. It is believed these figures show that *in the case of pickle and kraut wastes some factor or factors other than B.O.D. loading materially affect the B.O.D. reduction but, if those factors could be eliminated, biological filtration would be at least as effective in treating such wastes as it is in treating sanitary sewage.*

It is well known that most of the organisms responsible for biological oxidation are sensitive to the hydrogen ion concentration of their medium. Presumably the optimum pH is somewhere between 7.0 and 7.6 for whenever slightly more acid or more alkaline wastes are treated biologically, the pH of the effluent tends to rise or fall to this range.

In the case of the pickle and kraut wastes we found that invariably there was an increase both in alkalinity and pH as a result of treatment. However, the pH of the effluent ranged from 4.2 to 7.6. In Fig. 3 and 4 the percentage reductions in B.O.D. are plotted against effluent pH. (Since pH is the negative logarithm to the base 10 of the hydrogen ion concentration, the effluent pH has been plotted on a logarithmic scale.) Fig. 3 shows the reduction in total applied B.O.D., while Fig. 4 shows reductions calculated on the basis of raw waste only. The data indicate a direct straight line relationship between hydrogen ion concentration and percentage reduction in B.O.D. for all reductions of less than 75 per cent. In Fig. 4 the line curves upward for higher removals and approaches a vertical at 93 per cent for a pH range of 6.9 to 7.6. This is to be expected for, even in the optimum pH zone, the reduction could never be 100 per cent.

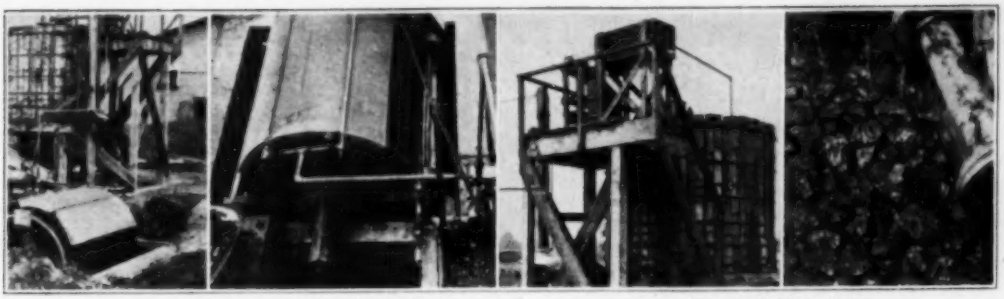
It will be recalled that Fig. 1 and 2 indicated that under favorable conditionus it was possible to obtain reductions of 53 per cent in total applied B.O.D., or 90 per cent in the B.O.D. of the raw wastes alone. Fig. 3 and 4 show that such reductions can be expected only when the pH of the effluent is 6.6 or higher. Therefore, it is concluded that *if a biological filter is to provide maximum treatment of acidic wastes, it is essential it be so operated that the pH of its effluent does not fall below 6.6.* An 85 per cent reduction in raw waste B.O.D. might

TABLE III

COMPARISON OF B.O.D. REDUCTIONS ON DAYS OF PARTICULARLY HIGH OR LOW CHLORIDE CONCENTRATION

Date in 1949	Chlorides in Effluent ppm	pH of Effluent	BOD Removal % of Raw Waste BOD		BOD Removal % of Total BOD Applied	
			Observed	Expected From Fig. 4	Observed	Expected From Fig. 3
10-19	5800	4.6	23.9	37	4.7	5
10-18	5930	4.9	38.1	33	8.7	8
9-9	5010	5.3	91.6	66	71.8	27
10-5	4430	5.8	92.6	62.5	12.9	33
10-20	4390	4.6	29.8	37	9.3	5
9-1	1215	6.35	43.9	88	15.5	46
9-13	1225	6.2	85.0	87	45.6	45
9-17	1310	6.7	98.5	91	50.0	53
10-7	1690	5.75	86.4	80	36.5	37

CHLORIDE CONCENTRATION AND EFFECT ON B.O.D.



Permanent "North" Screen Handling Raw Wastes
Shower pump delivered screened waste
to the treatment plant

Filter, Orifice Boxes, and Filter Media
Infilco orifice measures raw wastes,
Yeoman's distributor applies them

be expected if the pH of the effluent does not drop below 6.0.

The average chloride content of the pilot plant effluent on the 32 sampling days was 3,021 p.p.m. On five occasions it was above 4,000 and on four occasions it was below 2,000. In Table IV the actual B.O.D. reductions observed on those days are compared with the reductions that would be expected from the pH of the effluent and Fig. 3 and 4. Although the observed reduction did not always agree with the expected, the variation was as great for the low chlorides as for the high. In both cases, some of the observed results were higher than expected, while others were lower. Therefore, it is concluded that *chloride concentrations up to five or six thousand parts per million have little, if any, effect on the biological efficiency of a filter.*

In Fig. 5 and 6 the pH of the effluent has been plotted against (a) total and (b) raw waste. B.O.D. filter loadings. The figures show a definite relationship to exist between filter loading and effluent pH. Since maximum B.O.D. reduction cannot be expected at a pH below 6.6, it would appear desirable to limit the filter loading to 2,300 pounds of B.O.D. per 9 hour day on the basis of raw waste plus recycle, or to 1,200 pounds on the basis of raw wastes alone. If an 85 per cent B.O.D. reduction is considered satisfactory, then the pH could drop to 6.0 and the corresponding filter loadings might be 3,300 and 1,700 pounds respectively.

These loadings are, of course, only averages. Since satisfactory treatment has been obtained, upon occasion, despite much higher loadings, and since there is such a definite relationship between effluent pH and degree of treatment, it seems logical to conclude that considerably greater B.O.D. loadings could be handled satisfactorily if effluent pH was controlled continuously by application of an alkali to the filter influent. The advent of cold weather made any attempt to confirm this conclusion impractical at Albro. However, Sanborn[1] has already proved it for less acid wastes such as those from pea and corn canneries. Alkali treatment should be of even greater benefit in the case of the more acid kraut and pickle wastes.

It is generally agreed that the capacity of a given filter can be increased by recycling final effluent through the filter one or more times. For municipal sewage, Walton[4] concluded that recirculation was effective in increasing B.O.D. reduction so long as the total filter loading (sewage and recycle) did not exceed 1.2 pounds per square foot per day (equivalent to 8,700 pounds per acre foot per 24 hours for a filter 6 feet deep). Mohlman, Thomas, et al[5] presented data to show that increasing amounts of recirculation up to a recycle ratio of 8 result in higher filter efficiencies at military plants, but that more recycle may be deleterious. Warrick, McKee, Wirth and Sanborn[6] found the efficiency of a trickling filter treating corn cannery wastes to be a function of the contact between the filter media and the waste. They state that this contact may be obtained by using either a small filter with a number of recirculations, or a larger filter with fewer recirculations.

It was found that the effluent from the treatment of kraut and pickle wastes usually contained appreciable alkalinity: 235 p.p.m. average. Recirculation made this alkalinity available for partially neutralizing the acidity of the raw wastes. Therefore, it was expected that a high recycle ratio would be even more advantageous in treating kraut and pickle wastes than it was in treating sewage or less acid wastes. However, as shown by Fig. 7 and 8, the Albro data indicated absolutely *no correlation between*

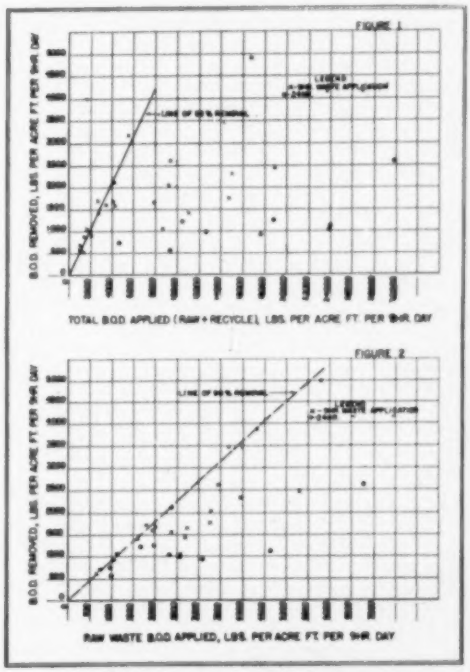


FIGURE 1
B.O.D. REMOVED, LBS. PER ACRE FT. PER 9HR. DAY
TOTAL B.O.D. APPLIED (RAW + RECYCLE), LBS. PER ACRE FT. PER 9HR. DAY
FIGURE 2
B.O.D. REMOVED, LBS. PER ACRE FT. PER 9HR. DAY
RAW WASTE B.O.D. APPLIED, LBS. PER ACRE FT. PER 9HR. DAY

Fig. 1 & 2—Filter Loading and B.O.D. removal

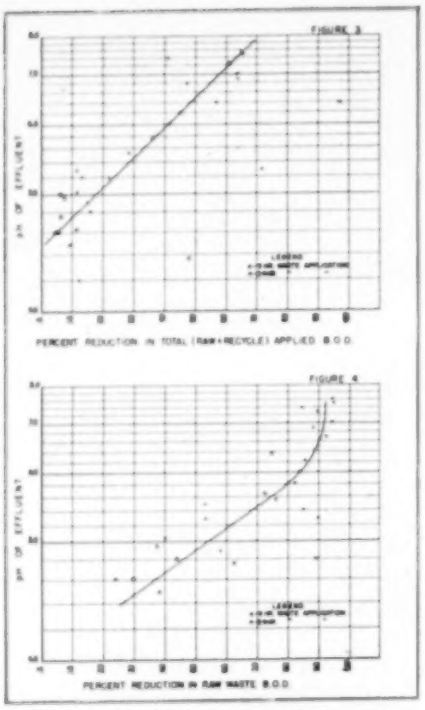


Fig. 3 & 4—B.O.D. Reduction and pH relationship

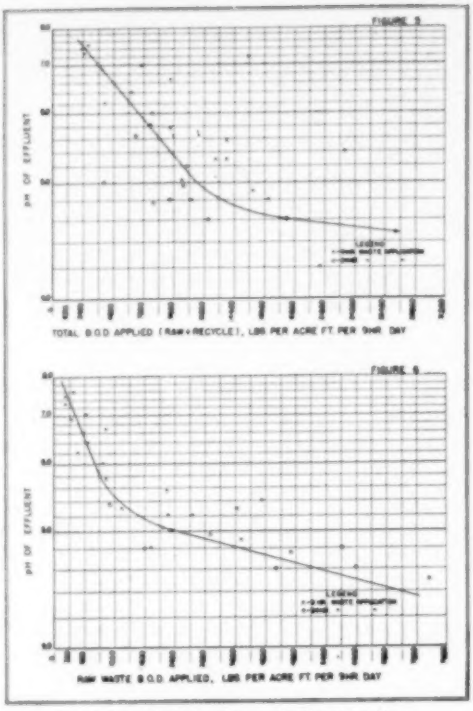


FIGURE 5
pH OF EFFLUENT
TOTAL B.O.D. APPLIED (RAW+RECYCLE), LBS. PER ACRE FT. PER 9HR. DAY
FIGURE 6
pH OF EFFLUENT
RAW WASTE B.O.D. APPLIED, LBS. PER ACRE FT. PER 9HR. DAY

Fig. 5 & 6—B.O.D. Loading and pH relationship

recycle ratio and B.O.D. reduction. In the writer's opinion, this contrast between biological filtration of highly acid wastes and that of more nearly neutral wastes is the most important lesson to be learned from the Albro experiment.

Since no treatment accomplishes 100 per cent B.O.D. removal, it is obvious that increasing the amount of recirculation increases the total applied B.O.D. It has been shown that increasing the applied B.O.D. loading reduces the pH of the effluent and hence the percentage removal of B.O.D. This may be the explanation of the condition. However, the "treatability" or ease of oxidation of the organic matter may also enter the picture. Organic matter varies in its "oxidizability." This may not be of great importance in the case of a lightly loaded filter, but if the filter is heavily loaded, it seems reasonable to expect that only the most easily oxidized material would be acted upon during the first pass through the filter. Although succeeding passes might result in further oxidation, it is apparent that increasing the amount of recirculation would not only increase the total applied B.O.D. load, but would also increase the proportion of organic matter difficult of oxidation in that load.

In the Albro studies, the B.O.D. of the recycle ranged from 27.5 to 89.9 per cent of the total applied B.O.D. In Fig. 9 and 10 these percentages have been plotted against the percentage reductions in B.O.D. of the total filter influent and raw wastes, respectively. It will be noted that each curve has an inflection point where the B.O.D. of the recycle was about 75 per cent of the total B.O.D. applied. If the recycle B.O.D. is greater than that percentage, the efficiency falls off very rapidly. As the proportion of recycle B.O.D. decreases below 75 per cent, the treatment efficiency increases almost directly. However, Fig. 10 indicates that another inflection point may occur when the recycle B.O.D. drops below 40 to 35 per cent of the total applied. Since treatment efficiency can never be 100 per cent, it is obvious that such an inflection point must exist on both curves even though the data presented does not clearly define it.

At any event, the data indicate that if the maximum efficiency, as defined by the straight lines in Fig. 1 and 2, namely 53 per cent removal of total B.O.D. or 90 per cent removal of raw waste B.O.D., is to be obtained, the B.O.D. of the recycle should be less than 40 per cent of the total applied B.O.D. Mathematically this would mean that the recycle ratio should not exceed 7. Although that value happens to be close to the maximum ratio of 8 set by Mohlman and Thomas[8] for military installations, the lack of correlation between plant efficiency and recycle ratio shown in Fig. 7 and 8 clearly indicate that, at least for acid wastes, it is the B.O.D. rather than the volume of recycle which is important. It was previously stated Fig. 5 and 6 indicate that, to accomplish the best treatment results, loadings should not exceed 1,200 pounds of raw waste B.O.D., or 2,300 pounds of total B.O.D. Under that condition the recycle B.O.D. would be 56.5 per cent of the total. Perhaps a raw waste loading as high as 1,400 to 1,500 pounds would be permissible if the B.O.D. of the recycle did not exceed 1,000 pounds per acre foot per 9 hour day.

Obviously some recycle is essential in a cannery plant to prevent drying out of filter growths during nights or weekends when the cannery is not operating. Furthermore, it is generally agreed that filters subjected to high B.O.D. loadings must also be subjected to high dosing rates to prevent clogging or ponding. A dosing rate of 8 to 12 million gallons per acre per 24 hours is generally

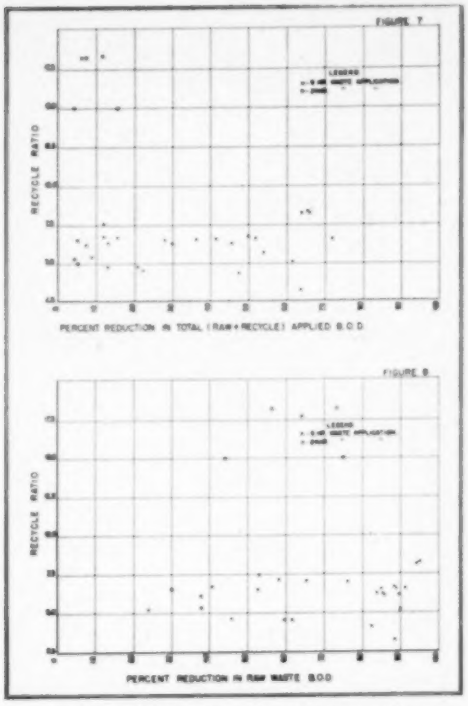


Fig. 7 & 8—B.O.D. and recycle ratio lack correlation

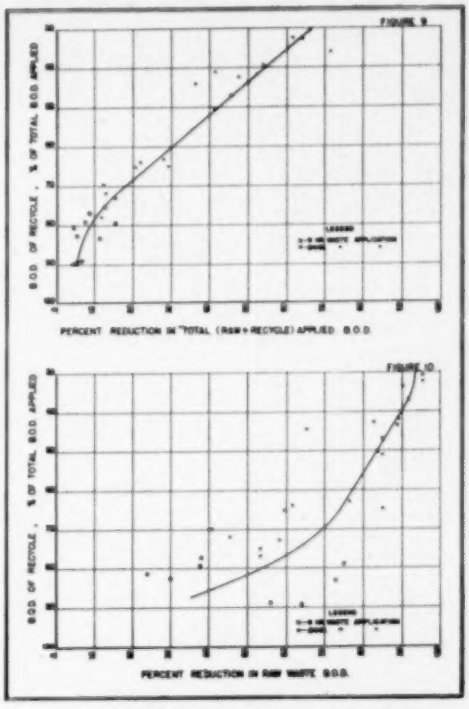


FIGURE 9
B.O.D. OF RECYCLE, % OF TOTAL B.O.D. APPLIED
PERCENT REDUCTION IN TOTAL (RAW + RECYCLE) APPLIED B.O.D.
FIGURE 10
B.O.D. OF RECYCLE, % OF TOTAL B.O.D. APPLIED
PERCENT REDUCTION IN RAW WASTE B.O.D.

Fig. 9 & 10—B.O.D. Reduction and recycle loading

stated to be the minimum permissible. In the Albro experiments, the dosing rate ranged from 9.1 to 30.2 m.g.a.d. No ponding or clogging was observed. Although sludge production varied considerably, there was no correlation between it and either the dosing rate, the recycle ratio, or the B.O.D. loading. In general, sludge production seemed to be greatest when the top filter growth exhibited the green or brown color generally observed on well operating municipal filters. At the times the color of growth on the filter stone was grey, flecked with black. On such occasions the filter had an objectionable "sour" odor and was undoubtedly in poor condition despite the absence of ponding. At intermediate stages the top growth exhibited an orange color ranging from almost yellow or pink to a deep red. The writer has observed a similar color on filters treating milk wastes, but never on those treating domestic sewage. The color may be characteristic of moderately heavy loads at low pH.

The data for the entire 109 days of operation indicate that about 252 gallons of sludge containing 81 pounds of total solids, or 47 pounds of volatile solids, was produced per 1,000 pounds of B.O.D. removed. However, the plant was operated for such a short period under such variable conditions that these averages may be without significance. The sludge had a pH of 5.0 to 6.0 and an alkalinity of 600 to 1,400 p.p.m. as $CaCO_3$. It would dry on conventional beds more rapidly than digested sludge from the Meadville, Pennsylvania municipal sewage plant, but might give off objectionable odors while doing so. The sludge was readily digestible without seeding but produced very little gas.

Some trouble was encountered with partial stoppage of effluent return piping due to the development of grey filamentous growths. In permanent plants such piping should be readily accessible for cleaning.

References

(1) N. H. Sanborn, "Treatment of Vegetable Cannery Wastes," Industrial Engineering Chemistry, Vol. 34, p. 911 (August 1942).

(2) Graham Walton, "High Daily Rate Trickling Filter Performance Under the Direction of the Board of State Health Commissioners Upper Mississippi Basin Sanitation Agreement," March 1943.

(3) "Sewage Treatment at Military Installations," Sewage Works Journal, Vol. 18, p. 975 (September 1946).

(4) L. F. Warrick, F. J. McKee, H. E. Wirth and N. H. Sanborn, "Methods of Treating Cannery Wastes," Bulletin 28-I. National Canners Association, December 1939.

160 Tons of Hot Water per Family per Year

A manufacturer of hot water heating system equipment has completed a survey on the needs of the average family for hot water—in order to determine the proper size of water heaters.

Conclusion: the amount of hot water used in one year by a family of three would float a submarine chaser! The survey shows a family of this size uses between 25,000 and 40,000 gallons of hot water per year—or from 100 to 160 tons.

Those who linger in a shower or take deep baths may require as much at 40 gallons more hot water per day, or over 15,000 gallons a year. The average adult uses about 20 gallons of hot water a day.

Neutralization Nomograph

For Determining Relative Volumes of Acidic and Basic Solutions for Neutralization

by RICHARD D. HOAK, *Senior Fellow, Mellon Institute, Pittsburgh, Pa.*

ACIDIC and alkaline waste waters generally must be neutralized before discharge to a stream or sewer system. Where both types of waste are produced in the same industrial plant it is good economy to combine them, if practical to do so. If the wastes are approximately equivalent in neutralizing value, it is only necessary to install equipment that will provide thorough mixing. Often, however, the wastes are not equivalent, and a neutralizing agent must be added to supplement the weaker waste.

The accompanying nomograph provides a quick method for determining relative volumes of waste water that must be combined for neutralization. It can also be used to determine the amount of neutralizing agent that must be added to make the weaker waste equivalent to the stronger, or the volume of neutralizing solution to prepare where only one type of waste is produced.

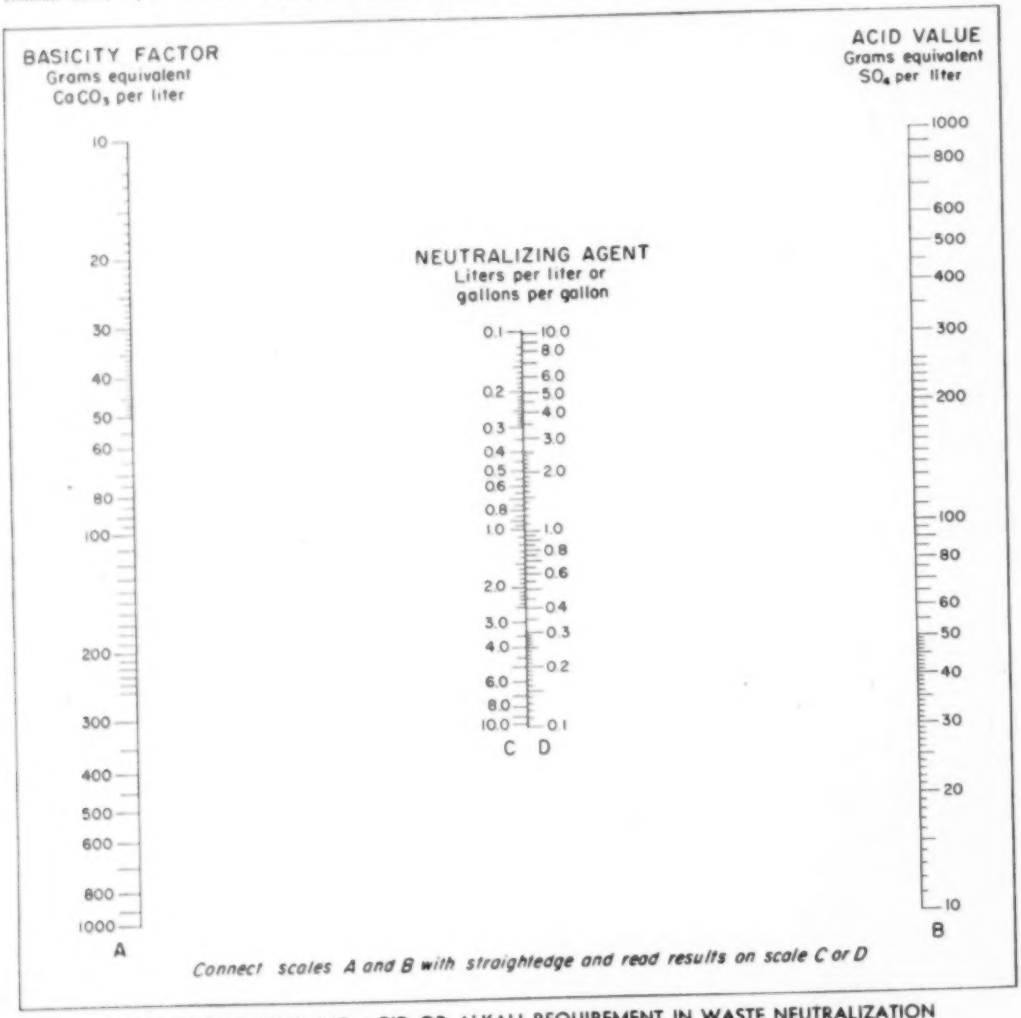


CHART FOR DETERMINING ACID OR ALKALI REQUIREMENT IN WASTE NEUTRALIZATION

Neutralization normally is most efficient where wastes are relative dilute, rather than concentrated. For example, if lime slurry is the neutralizing agent it should contain only about a pound of lime per gallon, or roughly the equivalent of 200 g. $CaCO_3$/l. This is especially important where the acidic waste contains salts of heavy metals that form hydrous oxides.

Determining Basicity

The basicity on the nomograph was calculated in terms of equivalent calcium carbonate, to conform with usage in water treatment practice. It is determined by titrating a sample with a strong acid to a phenolphthalein endpoint, according to the procedure given for alkalinity in Standard Methods. In the method cited, results are calculated as parts per million; this figure must be divided by 1000 to get grams per liter. If the alkaline waste is quite concentrated, a representative sample should be diluted with distilled water in a volumetric flask and an aliquot pipetted for titration. For example, if a 10 ml. sample is diluted to 100 ml. and 10 ml. of this solution is titrated, only 1 ml. of the actual waste will be used in the titration. More accurate results will be obtained in this manner than by pipetting 1 ml. of the waste directly.

Where an acid liquor is to be neutralized with lime, it is the available alkalinity that is important, whether present as calcium oxide or some other constituent of the lime. The complete chemical analysis of lime is time-consuming, and, for various reasons, such an analysis may not yield the actual neutralizing value of the material. It is preferable to determine the available basicity of lime as follows.

Procedure. Using a weighing bottle, weigh accurately about 1.3 grams of lime and transfer the sample to a small procelain crucible. Place the crucible upright in a 250-ml. beaker containing 15 ml. of water. Cover the beaker, heat the water to boiling, and tip the crucible to fill it with the hot water. Allow to stand for several minutes to slake the lime completely. Scrub the crucible inside and out with a rubber policeman, wash and remove it, run in from a burette the approximate quantity of 0.5 N sulfuric acid required to react with the lime, then add 30-35 ml. in excess. Wash the mixture into an Erlenmeyer flask, boil about 10 minutes, make up evaporation loss with water, cool to room temperature, add a few drops of phenolphthalein indicator, and titrate with 0.5 N sodium hydroxide to the first appearance of a pink color. The basicity, as grams of equivalent $CaCO_3$ per gram of sample, is calculated as follows:

$$\frac{0.05\ (\text{ml. } H_2SO_4 \times N - \text{ml. NaOH} \times N)}{\text{g. sample}} = \text{g. } CaCO_3/\text{gram}$$

For limes of good quality, basicities will approximate the values given in the table.

	g.Equiv. $CaCO_3$/g.
High calcium quicklime	1.7
High calcium hydrate	1.3
Dolomitic quicklime	2.0
Dolomitic hydrate	1.6

Quicklime should be slaked by adding just enough water, preferably warm, to form a heavy slurry; too much or too little water will reduce its reactivity. When slaking is complete (15-30 minutes), enough water should be added to produce a milk of lime of proper density; usually about one pound of dry lime per gallon of water will be best for neutralization. If hydrated lime is used it should be suspended in water before being added to the acidic waste, or its full neutralizing value will not be obtained.

Determining Acidity

Acidities are determined by titration with a strong base to a phenolphthalein endpoint, by the method given for acidity in Standard Methods. Here the results are calculated as parts per million of calcium carbonate; to convert this figure to grams of equivalent sulfate ion per liter, divide by 960. The comment given above on titrating strong solutions applies here also.

Where the acidic waste contains salts of heavy metals, the following method is recommended.

Procedure. Pipette 5 ml. of the acid liquor into 50 ml. of distilled water in a 250-ml. beaker. Run in from a burette 25-30 ml. of 0.5 N sodium hydroxide in excess of that required for complete reaction. Heat to boiling for 2-3 minutes, stirring to avoid loss by bumping. Wash the mixture into a 250-ml. volumetric flask, cool to 20°C., make up to the mark with distilled water, mix, and allow the precipitate to settle. Pipette 100 ml. of the clear supernatant into a beaker, add several drops of phenolphthalein indicator and titrate with 0.5 N sulfuric acid to the first appearance of a pink color. The acidity, as grams of equivalent sulfate ion per liter, is calculated as follows:

$$\frac{48\ (\text{ml. NaOH} \times N - \text{ml. } H_2SO_4 \times N \times 2.5)}{\text{ml. sample}} = \text{g. } SO_4/L$$

Depending on the strength of the original waste, it may be necessary to use a sample larger or smaller than the 5 ml. indicated in the procedure. Acidities can be determined by this method in about 20 minutes with an accuracy of 0.2 per cent.

Using the Nomograph

The precision of a nomograph is governed only by the scale on which it is constructed and the accuracy of the data on which it is based. The nomograph reproduced here was drawn as carefully as possible without a dividing engine, and the data are theoritically accurate; it should be wholly dependable for general neutralization practice. It will be observed that all scales are logarithmic; care must therefore be exercised in estimating values where a straight line cuts the scales between divisions.

Use of the nomograph can best be illustrated by examples. Assume an alkaline waste containing 200 g./l. equivalent calcium carbonate and an acid waste of 125 g./l. equivalent sulfate. Connect 200 on Scale A with 125 on Scale B, and read 1.54 on Scale C; this means that a liter of alkaline waste will neutralize 1.54 liters of acid waste. On Scale D read 0.66, indicating that a liter of the acid waste will neutralize 0.66 liters of alkaline waste. If now a line be drawn from 200 on Scale A through 1.0 on Scale C to its intersection on Scale B, the figure 192 can be read. This means that the strength of the acid waste must be increased by 67 g. SO_4/l. (192 — 125 = 67) to make the two wastes volumetrically equivalent. It is obvious from this example that the alkaline waste will require 192 grams of equivalent sulfate per liter for neutralization, regardless of the concentration of the acid waste. Estimation of relative volumes of acid waste in terms of alkaline is made similarly. It need only be remembered that Scales A and C are used to determine the volumetric acid/base ratio, and Scales B and D the base/acid ratio. In using the chart it is helpful to consider a unit volume of one waste and determine its strength in terms of the other. It this is done it will be easy to decide the relative volumes to combine for neutralization.

John Downes Is Dead

Sewage Treatment Pioneer and Inventor.

John R. Downes, for many years Supervising Engineer in charge of the Sewage Treatments Works of the Joint Meeting of Plainfield, North Plainfield and Dunellen, N.J., passed away in Neddick, Me., on February 11th, only a little more than a year after his retirement. He was 68 years old.

John Downes was born Nov. 29, 1884 in Oneonta, N.Y. After graduation for Renssaeler Polytechnic Institute, he became city bacteriologist of Harrisburg, Pa. He went to Panama in 1907 and had charge of water supply for the Panama Canal until 1912 when he became connected with the Plainfield Joint Sewage Treatment Plant.

Mr. Downes was a pioneer in sewage treatment in America and was an organizer of the nation's oldest sewage works association—the N.J. Sewage Works Assn., which he served as its first president, and thereafter as its secretary-treasurer and editor for twenty-five years or more.

John Downes did much to advance sewage treatment and was inventor of the well known Downes Flating Cover for sludge digestion tanks. He also developed the flotation process for sludge concentration and a unique method of spray flash-drying the sludge for marketing as fertilizer.

Because of ill health he retired in January 1951 and had been residing in Maine since.

> The man who does not read good books has no advantage over the man who can't read them.—*Mark Twain*

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HYPERION Sewage Treatment Plant of Los Angeles, Calif.

Flow-Ratio Metering by Logarithms at Hyperion Sewage Treatment Plant

by JACK M. BETZ, *Civil Engineer, City of Los Angeles, Calif.*

IN the efficient operation of an activated sludge plant, one of the most important criteria is the air-sewage flow ratio expressed as the cubic feet of air supply per gallon of sewage treated. If the air flow A, expressed in cubic feet per minute, and the sewage flow S, expressed in gallons per day, are known—

$$\text{Cu. Ft. of air per Gal. of sewage} = \frac{A \times 1440}{S}$$

Instead of the frequent computation of this ratio during each day's operation, it is apparent that a meter continuously giving this value would be of great service. This article will describe an instrument which indicates the air/sewage ratio on a dial, also the return sludge/sewage ratio, using only standard units manufactured by Builders-Providence, Inc. The installation is in the new Los Angeles Hyperion Activated Sludge Plant and it has functioned in a highly satisfactory manner.

Air/Sewage Ratio

Figure 1 shows, diagrammatically, the metering assembly. In this diagram *SE* is one of two Pneumatic Transmitters which respectively receive the inlet and throat pressures from Venturi Tubes in the two 108 inch raw sewage mains. These Transmitters are so designed that the output from each is a single air pressure proportional to the rate of flow through the Venturi Tube to which it is connected. The Summator Unit receives and integrates these two pressures and sends out a single air pressure, proportional to the *sum* of the rates of flow of sewage through the two Venturis, to the Logarithmic Transmitters *LS* and *LSE*, each receives the proportional pressure and converts it to an output pressure equivalent to the logarithm of the total measured flow in the two Venturi tubes.

A is one of two Pneumatic Transmitters which respectively receive the differential pressure created by Orifice Plates in the two 66-inch air mains. The output from each Transmitter is a single air pressure proportional to the rate of flow through the orifice. Similar to the sewage unit, the Air Summator receives and integrates these two pressures and sends out a single air pressure to the Logarithmic Transmitter *LA*. This single air pressure is proportional to the *sum* of the rates of flow of air through the 66-inch air lines.

Log-Transmitters *LS* and *LA* (Fig. 2) transmit air pressures respectively proportional to the log of the total flow of sewage and of air. These functions are performed mechanically by standard Pneumatic Transmitters. Mounted at the back of each of these Log-Transmitters is a conventional U-tube mercury well: the high pressure well receives the transmitted pressure from the Summator; the low pressure well is vented to atmosphere. A float in the latter moves vertically as the displaced mercury rises, and rotates a specially-shaped cam. The cam follower positions an air nozzle-flapper to produce an output pressure proportional to the logarithm of the total flow from the Summator.

For example: if the total air flow is 140,000 cubic feet per minute, the resulting air output pressure is proportional to the log of the flow and is equivalent to 56 inches of water differential: the actual value is 9.967 psi.

The Sewage Log-Transmitter (*LS*) functions in an entirely similar manner: if the total sewage flow is 288 mgd., the output pressure is 11.314 psi.

Logarithmic Computer

It is now necessary to subtract the pressure proportional to the log of the

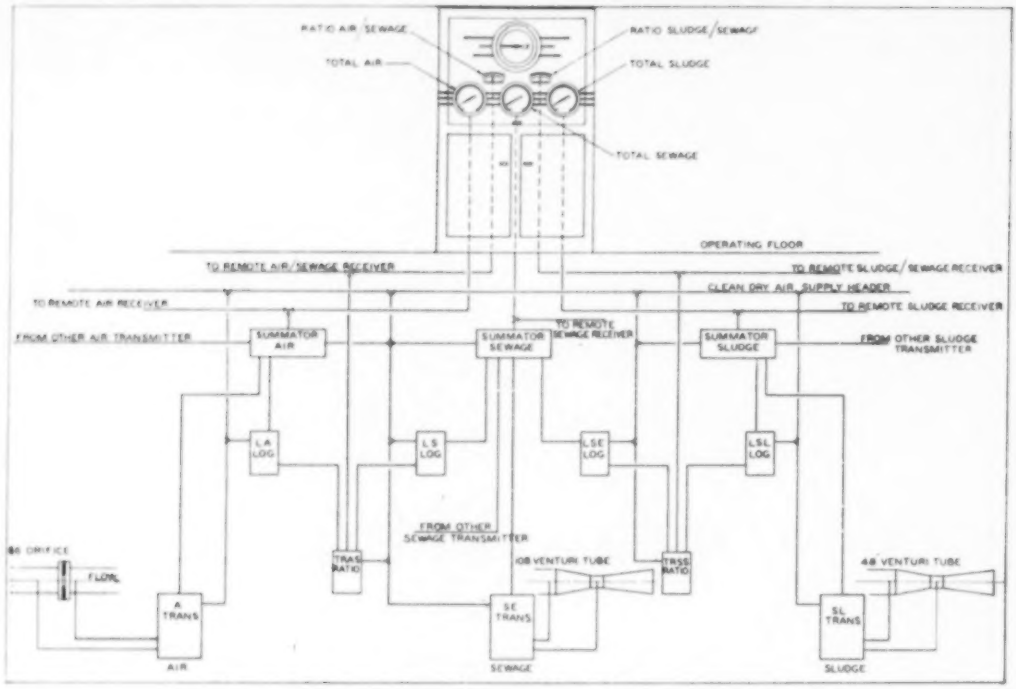

Fig. 1—Diagram of Flow-Ratio Metering at Hyperion Sewage Plant

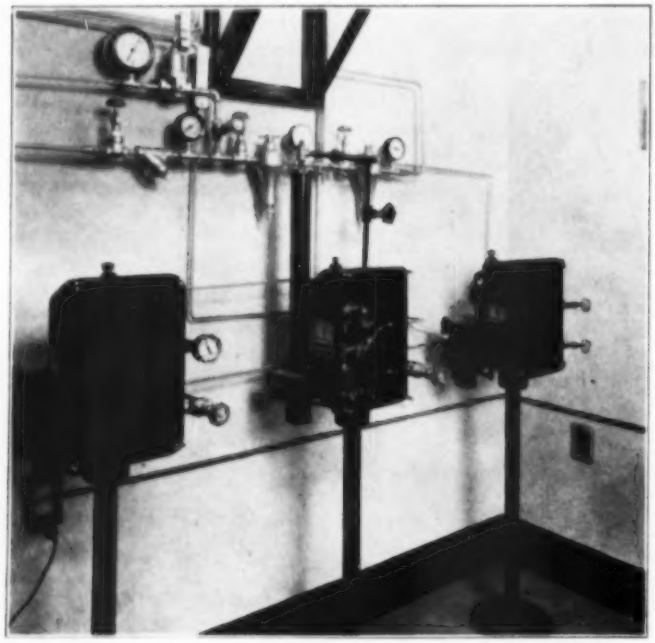

Fig. 2—Log Transmitters LA (air, left) and LS (sewage, right) and Anti-Log Computer TRAS (air/sewage ratio, center)

sewage flow rate from the pressure proportional to the log of the air flow rate. The fundamental determination of the ratio relation can be readily understood by anyone familiar with logarithms, or the slide rule, which is graduated on the logarithmic basis. The division of one number by another is performed by subtracting the distance on the rule corresponding to the denominator from the distance corresponding to the numerator. The remaining distance from the index represents the quotient, which can be read directly.

The final unit *TRAS* (Fig. 2) termed the Anti-Log Computor, accomplishes this task.The two pressures, one from the Air Log-Transmitter (*LA*) and the other from the Sewage Log-Transmitter (*LS*) are connected to a mercury U-tube at the back of the Computor, and the mercury column will be displaced an amount equal to the difference in these two pressures. In other words, the logarithms of the air and sewage flow rates are thus subtracted mechanically. A cam and air-flapper element is similar to those described.

For the two flow rates mentioned, the output air pressure from the Computer (*TRAS*) to the Air/Sewage

Fig. 3—Builders-Providence Ratio Gauge, for air/sewage and return sludge/sewage, in Chief Engineer's office

Ratio Receiver Indicator on the instrument panel (Fig. 3) will be 6.846 psi. and the resulting reading 0.70 cubic feet of air per gallon of sewage.

Sludge/Sewage Ratio

The flow ratio of return sludge to incoming sewage is accomplished in exactly similar manner (See Fig. 1) through the two *LS* Transmitters to the sludge Summator, thence to the *LSL* Log-Transmitter for sludge and then to Ratio Transmitter *TRSS*, which receives the sewage flow through Log Transmitter *LSE*. Inasmuch as the mechanics of this system are the same as that described for air/sewage, no further description is necessary.

At the Hyperion Plant, three Air/Sewage Ratio-Indicators are provided: one on the aeration system Process Control Board; one in the chief engineer's office; one in the assistant chief engineer's office. Only one set of Anti-Log Computers is required and the connecting Instruments, located remotely, are connected by small copper tubing.

The method described is, of course, applicable to any type of ratio indication.

Recently Created N.P.A. Water & Sewage Works Advisory Comm. Holds First Meeting

Discussion of a proposed order centralizing various regulations affecting water and sewerage systems and liberalizing some existing provisions highlighted the first meeting of the Water and Sewerage Industry Advisory Committee with the National Production Authority over which G. E. Arnold, Director, Water Resources Div., presided.

The proposed order chiefly concerns inventories, maintenance, repair and operating supplies, self-authorization for controlled materials and use of new allotment and preference rating symbols.

City engineer members of the committee agreed that many smaller municipal and private systems are operating in ignorance because of the number and complexity of NPA regulations. They asked for maximum simplification in the contemplated order, and that all substantive provisions concerning their industry be incorporated in a single document.

The committee recommended that:

1. Inventory limtations for their industry be liberalized (from the present 45 days on steel and aluminum and 60 days on copper items) to 90 days on copper and brass goods, and, for steel materials, to the minimum practicable working inventory required for safe operation of a facility. They also asked an inventory distinction between items required for new projects and items needed for repair and maintenance work, which are normally stocked in quantities sufficient to satisfy several years' requirements.

2. Self-authorization for water and sewerage systems be raised from the present limit of two tons of carbon steel and 200 pounds of copper to a maximum for each project in any one calendar quarter of 20 tons of carbon steel (excluding structural steel), four tons of structural steel, one ton of alloy and stainless steel, 500 pounds of aluminum and 1,500 pounds of copper and copper-base alloys, including not more than 1,000 pounds of copper tubing.

A "minor capital addition" is defined in the proposed order as one on which the whole cost of materials—not merely controlled materials—does not exceed $100,000 for a system extension, $50,000 for a plant extension and $5,000 for industrial customer service or $1,000 for domestic customer service.

Discussing inventories, NPA explained that possession of excess inventories is not in itself a violation of inventory control regulations. A company having such an inventory, however, is prohibited from obtaining additional quantities of that particular item until its inventory has been reduced below the limitation.

The proposed order includes allotment symbols and preference ratings for use exclusively by the water and sewage works industry.

Inventory limitations on cast-iron pipe may be liberalized shortly to reduce the existing 45 day limit to a "practical minimum working inventory."

N.P.A. stressed the fact that "B" products, including water meters, valves, hydrants, etc., are not generally under inventory control.

The Industry Advisory Committee for Water & Sewage Works consists of the following members from the country at large:

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St. Louis, Mo.

THE EDITOR'S COMMENTS

A Court Decision With Implications

This issue contains a brief item reporting a recent decision of the Supreme Court of Texas on the legality of a city's rate schedule for water and sewer service charges to suburban residents which are in excess of charges for similar or the same service to those within the city limits.

The case at point is that of the City of Texarkana, Texas, which by ordinance has established a schedule of charges for water and sewer services within the city limits and a higher schedule of charges for customers residing in suburban areas which contribute no property taxes to the city. The situation in Texarkana is no different from that which prevails in practically every city that supplies water and/or sewer services to suburban areas. Therefore, the Texas Supreme Court's decision seems to be a highly important one and may well have ever widening implications and practical effects on rate schedules applicable to suburban water takers and sewer users.

The City of Texarkana, like many another, had established by ordinance rates for water service to suburban takers which carried a surcharge of 50 percent of the charge had the customer resided within the city limits. For sewer service the surcharge to be added was fixed at 100 per cent of the city-wide charge. In other words the suburban customer was paying one and a half times as much for water service and twice as much for sewer service, as was his neighbors residing across the city line. Nothing unusual about this method of charging more for suburban service. The court, however, has asked the perhaps embarrassing question—on what basis can such a marked differential in rates be supported by the city?

Although evidence presented to the Court by the Texas League of Municipalities revealed that the practice of charging higher rates for water and sewer service to property owners who did not contribute property taxes to the city's treasury was practically a universal practice, and a historically followed procedure, the Court would not concede such surcharges to be supportable on evidence presented. The Court had the following to say in its majority decision.

The Texarkana rate ordinance for water and sewer service is ruled void unless the city can prove beyond doubt that there is "a reasonable basis for the difference" in charges to those served on one side of the city boundary line as compared to the other. The decision is such as to call for a new trial of the case. What will happen will prove not alone of considerable interest to municipally owned utilities, but the Texarkana case may become a precedent which will create many similar cases where rate differences to suburban customers have prevailed for years unchallenged.

The minority opinion by the Court was simply to the effect that "The City of Texarkana is entitled to make its own terms and conditions in supplying water and sewer services to residents of North Texarkana." As against this broad opinion, the ruling opinion by the majority was to the effect that "a city cannot discriminate in fixing rates for so important utility services as water and sewer services, because those citizens outside the city limits have no other place to get water and sewer service." The Court further stated—"This decision is certainly in line with well established principles of public utility law."

It would appear that the majority opinion stemmed from the latter explanatory statement, which can only be interpreted to mean that the majority was of the opinion of previous Courts that municipal water and sewer service, when charged for on the basis of use by the property owner served, became a public utility operation rather than a governmental service such as those financed from taxes. Further substantiation of this viewpoint of the majority is found in the opinion that a municipality can legitimately charge higher rates for water and sewer services to persons living outside the city limits only if, and to the extent that, it can be shown that such services actually cost more than equivalent services provided those who reside within the city proper.

If all of the above is reduced to a fine point, and the precedent established in the Texarkana case is put to test at other points, municipally owned water and sewer departments are to have a troublesome period ahead combatting organized challenges of differential rates based principally on political boundaries. Does all of this mean the possibility of zone rates for water and sewer service, based on actual proven increasing overall costs of providing facilities and services in proportion to the distance that water and sewer mains are extended from the purification plant and pumping stations or sewer outfalls and sewage treatment plants?

Texarkana is not the only trouble spot in the water and sewer service charge picture. It is just one of the first cases to emerge from hearings or trials. There are other organized movements under way. These are piloted by capable and sharp legal minds, and in the same direction of attempting to secure court decisions which will force reduction of rates to suburban and county areas that are more realistic than those set arbitrarily by rule or ordinance which range from a moderate 25 per cent surcharge all the way up to what appears to be indefensible surcharges in some instances. If the courts rule that municipal utilities, like private utilities, have the right to charge only on the basis of actual cost of providing services, plus a reasonable profit allowance, many municipalities will be forced to re-examine the historic method of surcharging suburban residents and also industrial plants beyond the city limits.

The Texarkana case to our thinking is only a forerunner of others to come in many sections. These cases will but prove the wisdom and soundness of the Wisconsin and Maine practice of State Utility Commission regulation and guidance of municipally owned utilities, which practice has by and large kept such utilities in a satisfactorily healthy financial condition, less interfered with politically and happier by far in respect to operating personnel and management.

L. H. Enslow

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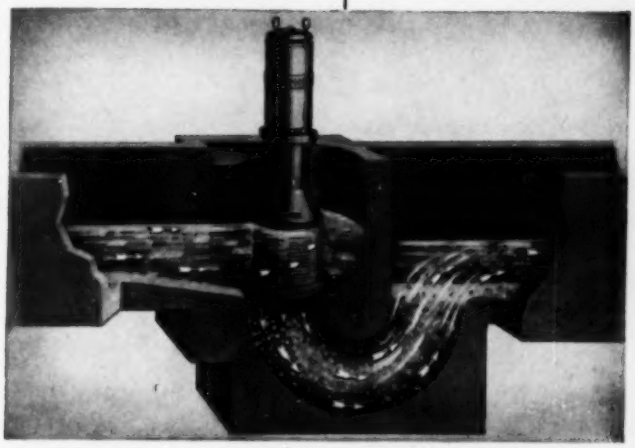

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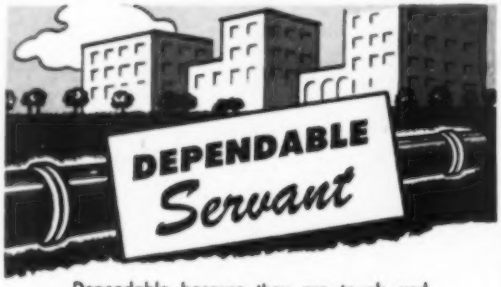

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Meetings Scheduled

Apr. 3-5—Mesa, Arizona *(Maricopa Inn)*
ARIZONA SEWAGE & WATER WORKS ASSOCIATION (and) ARIZONA SECTION A.W.W.A. Sec'y, H. S. Jordan, State Dept. of Health, Phoenix, Ariz.

Apr. 7-9—Fayetteville, Ark. *(University of Arkansas, Eng. Bldg.)*
ARKANSAS WATER & SEWAGE CONFERENCE. Dr. Harrison Hale, Southern State College, Magnolia, Ark.

Apr. 9—North Jay, Maine
MAINE WATER UTILITIES ASSOCIATION. Sec'y, Earle A. Tarr, Winthrop Water District, Winthrop, Me.

Apr. 10-12—Spartanburg, S.C. *(Clemson College)*
SOUTH CAROLINA WATER & SEWAGE WORKS ASSOCIATION. Sec'y, W. T. Linton, Wade Hamilton Bldg., Columbia, S.C.

Apr. 10—Billings, Mont. *(Northern Hotel)*
MONTANA SEWAGE & INDUSTRIAL WASTES ASSN. Sec'y, H. B. Foote, State Dept. of Health, Helena, Mont.

Apr. 11-12—Billings, Mont. *(Northern Hotel)*
MONTANA SECTION A.W.W.A. Sec'y, A. W. Clarkson, State Board of Health, Helena, Mont.

Apr. 16-18—Syracuse, N.Y. *(Hotel Syracuse)*
NEW YORK SECTION A.W.W.A. (Spring Meeting). Sec'y, R. K. Blanchard, 50 West 50th St., New York, N.Y.

Apr. 17—Kingston, R.I. *(Univ. of Rhode Island)*
NEW ENGLAND WATER WORKS ASSOCIATION. Sec'y, Jos. C. Knox, 204 Tremont Building, Boston, Mass.

Apr. 17-18—Washington, D.C. *(Wardman Park Hotel)*
MARYLAND-DELAWARE WATER & SEWERAGE ASSOCIATION. Sec'y, W. M. Bingley, 2411 No. Charles St., Baltimore, Md.

Apr. 17-18—Lincoln, Neb. *(Cornhusker Hotel)*
NEBRASKA SECTION A.W.W.A. Sec'y, E. Bruce Meier, University of Nebraska, Lincoln, Neb.

Apr. 18-19—Fayetteville, N.C. *(Public Works Warehouse Area-Russell St.)*
N.C. METER REPAIR & ALLIED ACTIVITY SCHOOL. Chairman, Stanford E. Harris, Dept. Water & Sewage, Winston-salem, N.C.

Apr. 24-26—Spokane, Wash. *(Davenport Hotel)*
PACIFIC NORTHWEST SECTION A.W.W.A. Sec'y, O. P. Newman, Boise Water Corp., Boise, Idaho.

May 3—Kansas City, Kansas *(Town House)*
KANSAS SECTION A.W.W.A. Sec'y, H. W. Badley, 640 Highland St., Salina, Kansas.

May 4-9—Kansas City, Mo. *(Municipal Auditorium)*
AMERICAN WATER WORKS ASSOCIATION (Annual Convention). Exec.-Sec'y, Harry E. Jordan, 521 Fifth Avenue, New York 17, N.Y.
(Accommodations in 14 hotels. Reservations through A.W.W.A. office.)

May 7-9—Lafayette, Ind. *(Purdue Memorial Union)*
7TH PURDUE INDUSTRIAL WASTE CONFERENCE. Director, Prof. Don E. Bloodgood, Purdue University, Lafayette, Ind.

May 12-13—Roanoke, Va. *(Hotel Roanoke)*
VIRGINIA INDUSTRIAL WASTES & SEWAGE WORKS ASSN. Sec'y, G. R. Talcott, 815 E. Franklin St., Richmond 19, Va.

May 15—Hanover, N.H. *(Dartmouth College)*
NEW ENGLAND WATER WORKS ASSOCIATION. Sec'y, Jos C. Knox, 204 Tremont Building, Boston, Mass.

May 21-23—Toledo, Ohio *(Commodore Perry Hotel)*
OHIO SEWAGE & INDUSTRIAL WASTES TREATMENT CONFERENCE. Sec'y, J. E. Richards, 301 Ohio Depts. Bldg., Columbus 15, Ohio.

May 26-28—Montreal, Canada *(Hotel Mt. Royal)*
CANADIAN SECTION A.W.W.A. Sec'y, Dr. A. E. Berry, Ontario Dept. of Health, Parliament Building, Toronto, Ont.

June 6—Auburn, Ala. *(Pitts Hotel)*
ALABAMA WATER & SEWAGE ASSOCIATION. Sec'y, Alex O. Taylor, Box 69, Alabama Polytechnic Institute, Auburn, Ala.

June 11—Houlton, Maine
MAINE WATER UTILITIES ASSOCIATION. Sec'y, Earle A. Tarr, Winthrop Water District, Winthrop, Me.

June 12—Portsmouth, N.H. *(Hotel Wentworth-by-the-Sea)*
NEW ENGLAND WATER WORKS ASSOCIATION. (June Conference) Sec'y, Jos. C. Knox, 204 Tremont Building, Boston, Mass.

June 18-20—Erie, Pa. *(Lawrence Hotel)*
PENNSYLVANIA SECTION A.W.W.A. Sec'y, L. S. Morgan, State Dept. of Health, Greensburg, Pa.

Aug. 13—Machias, Maine.
MAINE WATER UTILITIES ASSOCIATION. Earle A. Tarr, Winthrop Water District, Winthrop, Me.

Aug. 25-27—State College, Pa. *(Nittany Lion Inn)*
PENNSYLVANIA WATER WORKS OPERATORS ASSN. Sec'y, R. Rupert Kountz, Pennsylvania State College, State College, Pa.

Aug. 27-29—State College, Pa. *(Nittany Lion Inn)*
PENNSYLVANIA SEWAGE & INDUSTRIAL WASTES ASSN. Sec'y, B. S. Bush, Dept. of Health, Kirby Health Center, Wilkes-Barre, Pa.

Sept. 3-5—Upper Saranac, N.Y. *(Saranac Inn)*
NEW YORK SECTION A.W.W.A. Sec'y, Rollo K. Blanchard, 50 West 50th St., New York, N.Y.

Sept. 8-10—Groton, Conn. *(Hotel Griswold)*
NEW ENGLAND WATER WORKS ASSOCIATION (Annual Meeting). Sec'y, Jos. C. Knox, 204 Tremont Bldg., Boston, Mass.

Sept. 3-13—Chicago, Ill. *(Conrad Hilton)*
AMERICAN SOCIETY OF CIVIL ENGINEERS. (Centennial Celebration). Sec'y, Wm. N. Carey, 33 West 39th St., New York, N.Y.

Sept. 9-11—Grinnell, Iowa *(Grinnell College)*
IOWA SEWAGE WORKS ASSOCIATION. Sec'y, Leo Holtkamp, Box 310, Webster City, Iowa.

Sept. 10-12—Sioux Falls, S.D.
MINNESOTA SECTION A.W.W.A. Sec'y, L. N. Thompson, Water Dept., St. Paul, Minn.

Sept. 15-17—Knoxville, Tenn. *(Andrew Johnson Hotel)*
KENTUCKY-TENNESSEE SECTION A.W.W.A. Sec'y, R. P. Farrell, Dept. of Public Health, 420—6th Ave., Nashville, Tenn.

Sept. 15—Cheyenne, Wyo. *(Frontier Hotel)*
ROCKY MOUNTAIN SEWAGE WORKS ASSOCIATION. Sec'y, C. E. Harness, 272 City & County Bldg., Denver, Colo.

Sept. 16-17—Cheyenne, Wyo. *(Frontier Hotel)*
ROCKY MOUNTAIN SECTION A.W.W.A. Sec'y, Geo. J. Turre, Box 600, Denver, Colo.

Sept. 16-18—Madison, Wisc. *(Hotel Loraine)*
WISCONSIN SECTION A.W.W.A. Sec'y, L. A. Smith, City Hall, Madison 3, Wis.

Sept. 18-19—Cincinnati, Ohio.
OHIO SECTION A.W.W.A. Sec'y, F. P. Fischer, 812 Perry Payne Bldg., Cleveland 13, Ohio.

Sept. 21-23—Jefferson City, Mo.
MISSOURI SECTION A.W.W.A. Sec'y, W. A. Kramer, State Office Bldg., Jefferson City, Mo.

Sept. 24-26—Battle Creek, Mich. *(Post Tavern)*
MICHIGAN SECTION A.W.W.A. Sec'y, T. L. Vander Velde, Dept. of Health, Lansing 4, Mich.

Oct. 6-9—New York, N.Y. *(Statler Hotel)*
FEDERATION OF SEWAGE & INDUSTRIAL WASTES ASSOCIATIONS (Annual Meeting). Exec.-Sec'y, W. H. Wisely, 325 Illinois Bldg., Champaign, Ill. (and) NEW YORK SEWAGE & INDUSTRIAL WASTES ASSOCIATIONS. Sec'y, Ralph C. Sweeney, 21 N. Broadway, White Plains, N.Y.

Oct. 8—Bethel, Maine
MAINE WATER UTILITIES ASSOCIATION. Sec'y, Earle A. Tarr, Winthrop Water District, Winthrop, Me.

Oct. 12-15—Tulsa, Okla. *(Mayo Hotel)*
SOUTHWEST SECTION A.W.W.A. Sec'y, L. A. Jackson, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 14-17—Atlantic City, N. J. *(Chalfonte Hotel)*
PENNSYLVANIA WATER WORKS ASSOCIATION. Sec'y, W. A. Kufs, 510 Telegraph Bldg., Harrisburg, Pa.

(Continued on page 124A)

INVESTIGATE

BULKLEY, DUNTON PULP CO.

COLLOIDAIR

DISSOLVED AIR FLOTATION SYSTEMS

For Your Problem of:

SUSPENDED SOLIDS SEPARATION

A totally new process for high efficiency separation of—**suspended solids • oils and greases • recoverable by-products • industrial wastes**—from process or effluent flows.

Leading industries are utilizing this newest high efficiency-low space requirement method to economically—

- **Recover at a profit former waste materials**
- **Recover water for reuse**
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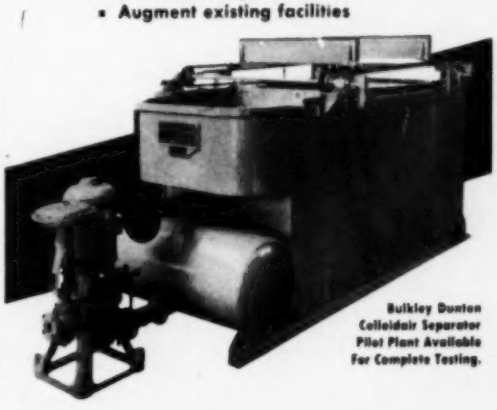

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- Meat packing
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- Railroad maintenance
- Fruit & vegetable canning
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- Leather & tanning
- Glue & gelatin manufacture
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SIMPLEX TYPE HF WEIR METER

IT'S SIMPLEX
IT'S ACCURATE

The Simplex Type HF water float operated meter is ingeniously adaptable to measuring liquid flows across weirs.

It may be considered as a standardized form of installation with weirs of the **Notched, Rectangular, Sutro, Broad Crested or Submerged types** for which mathematical flow formulae already have been developed. It may also be used with other types of weirs for which established flow formulae do not exist, but which permit laboratory or field rating to obtain the necessary head quantity relationship.

By its use, flow data is provided from any measurable maximum to ten percent of this maximum, the average error at any point over this range not exceeding plus or minus two percent.

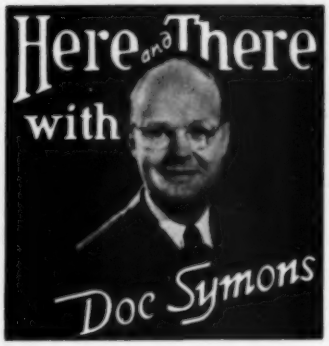
The Type HF Meter may be furnished as a wall mounted unit, for large panel installation or for individual steel floor stand mounting as shown.

Whenever a single head flow measuring instrument is required to operate with weirs of accepted design or otherwise, the type HF meter offers an excellent solution to this measuring problem.

Write to
Simplex Valve and Meter Company
Dept. 4, 6743 Upland St.
Philadelphia 42, Pennsylvania

SIMPLEX

VALVE AND METER COMPANY



Here's That Man Again—And this is the last time I shall mention the forthcoming AWWA Convention in Kansas City on May 4-9. I'm certainly looking forward to seeing all of you Water Works fellows including the D.P.B.'s (Dual Personality Boys) that handle both clean and dirty water (and there's a passel of 'em, too).—Next time I write about this convention, it will be in retrospect—Right now I'm looking forward to some mighty interesting technical sessions, a Western style Whooptedo, some K. C. beef steaks, perhaps a catfish fry, a bit of dancing and some more stories for this column.

* * *

E. Sherman Chase, Partner, Metcalfe & Eddy, Engineers, who always wanted to be called "Ed" and who is President of the NESIWA and Vice President of the Federation SIWA, Past President of NEWWA, etc. etc. never ceases to amaze me. An hour before he was scheduled to preside at a breakfast and open forum discussion of the NESIWA in Providence, I saw him sitting in the hotel lobby, hard at work. "Johnny" Horgan (Sales Manager, R. B. Carter Co.) opined that "Sherm" was getting his talk ready. But the effervescent Tom Bowe of Bowe, Albertson & Assoc. (N.Y.C.) peeked over Chase's shoulder and reported that "Sherm" was doing a cross word puzzle.

And at the NYSIWA annual meeting luncheon in New York in mid-January, at least one member of the audience found out it doesn't pay to heckle "Sherm" Chase, when he's on the speaker's platform.—"Sherm" talked about "Ghosts" of the era between the Spanish American War and World War I. Rather interesting to learn some of the forgotten sanitary engineering—But "Sherm" didn't tell his audience about the first report ever written on the chlorination of sewage. It was authored in 1914 by a young sanitary engineer in the New

(Continued on page 112A)

NEWPORT NEWS MECHANICAL RACK RAKE

WATER users troubled with trash are invited to write for new descriptive rack rake catalog.

THE Newport News Mechanical Rack Rake is a power-operated rake for cleaning trash racks at water intakes for hydroelectric plants, steam plants, pumping stations, canals and similar installations. It cleans the rack bars of trash and reduces a former major hand operation to one of minor periodic activity. With Newport News Mechanical Rack Rake installations, one man per shift can, under ordinary conditions, keep the racks clean for a dozen bays.

NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY

NEWPORT NEWS, VIRGINIA

(Continued from page 110A)

York State Health Department—one Edward Sherman Chase.

When I reminded him of it, he said, "Yes and that has a ghost in it for me. When *Water and Sewage Works* published that report about 35 years after it was written, I was embarrassed to read in the first paragraph the words, 'Data is . . .'" — you were younger then, "Ed."

* * *

New Feature:—I don't know how many of you are like I, but when you go to all these convention banquets and the menu is in French, do you wonder what you're going to have to eat? Well I do—So for my own edification and your amazement, I hope—I propose to start a regular feature on "Banquet French"— Let's take the a la's first.—In general "a la" means "in the manner of—etc." So—

a la Broche—Roasted on a skewer —as I hope you never are.

—carte—to order from the whole card (menu) not a set menu (which is "Table d'Hote") and be sure to read the right side of the menu, it "sure do add up fast."

—Creole—spicy like the Creole dishes (as aren't some of them that wear dresses).

—Diable—highly spiced or devilled (like another character).

—Jardiniere—doesn't mean cooked in a Jardiniere (remember them) but the meat is smothered in vegetables —lots of 'em.

—King—diced cooked fowl with mushrooms, pimentos and green peppers (Ugh!)

—Mode—"in fashion"—when it's a dessert there's ice cream on top; when it's pot roast there are herbs and vegetables on top; in the "Greasy Spoon" it's apt to be a scoop of lumpy mashed potatoes.

—Newburgh — creamed with a sauce of creamed egg yolks, wine (oh yeah) and butter.

—Provencale—prepared with olive oil and garlic with tomatoes and onions added—avoid, if you have a heavy date.

—Russe—in the Russian manner —but who knows what that is? I don't trust 'em!

Next month we finish the A's.

* * *

Small World No. 17—You know how it is when you're travelling by train and you drop into the club car to relieve the boredom. Frequently you get into casual conversation with your train companion. This conversation took place on a Pennsy train between New York and Pittsburgh. Two men were conversing about Providence, R. I., and the Grinnell Co. A third man, whose home is in Providence, joined the conversation thus:

No. 3—"Pardon me did I hear you mention Grinnell and Providence? I know a number of the fellows at Grinnell, are you new there?"

No. 1—"I'm with Grinnell out of New York but my friend is new in the Providence office."

No. 3 to No. 2—"That so, where do you live?"

No. 2—"On President Avenue."

No. 3—"I live on President Avenue at 234."

No. 2—"I live at 234."

No. 3—"What floor?"

No. 2—"Second floor."

No. 3—"I live on the second floor, too. You must be my new neighbor who moved in recently; we share the same back porch."

I'm sorry I don't know the name of Mr. No. 2 of Grinnell, but No. 3 was George Kelsey, B-I-F Industries VeeP.—Small World!

* * *

By the way, if you have any Small World items, send them to me, I'd surely love to have them.

(Continued on page 114A)

TANK
with a FUTURE
This tank in some respects looks like hundreds of others, but unlike many, it has a brighter future of longer life and greater service, because it is protected by an Electro Rust-Proofing system.
Efficient control of corrosion on submerged surfaces requires much engineering, some equipment. Careful analysis of your problem . . . design, installation and testing by men who are experienced in their work . . . the "know-how" of an established firm . . . "follow through" of every job—on these and similar engineering details rest effective cathodic protection.
Highly trained, backed by a long list of successful installations and years of experience, our engineer is always ready to help you solve your corrosion problem. For complete information, write today.
ERP-21
ELECTRO RUST-PROOFING CORP. (N. J.)
BELLEVILLE, NEW JERSEY
Over 15 years of cathodic protection engineering, research and development
COMPLETE CATHODIC PROTECTION SERVICE
DESIGN
ENGINEERING
INSTALLATION
MAINTENANCE
EQUIPMENT

New Plant at Fond du Lac...

combines refuse incineration and sludge disposal

A large part of the heat requirements at the new sludge drying plant at Fond du Lac, Wisconsin will be provided by a refuse incinerator. This combination arrangement is typical of the trend in smaller installations and effects considerable fuel savings.

Fond du Lac Plant, which went into operation in September of 1951 will serve an equivalent population of 75,500. It is equipped with a C-E Raymond Flash Dryer Unit designed to handle 15½ tons of filter cake per day, with an evaporation rate of 2,600 pounds per hour. Although the plant is located a short distance from a public park, the use of high temperature deodorization has completely eliminated objectionable odors.

The C-E installation at Fond du Lac is typical of C-E Raymond Systems now in service in virtually all parts of the country, meeting the varying requirements of both large and small communities. They are flexible in layout, highly efficient and thoroughly reliable; they provide for maximum utilization of waste heat.

The services of C-E specialists are available to assist you in finding the best solution to your sludge problem. Get in touch with the C-E office nearest to you for prompt attention. B-552

C-E Raymond Flash Dryer Systems installed, under construction or on order since 1945

BALTIMORE, Md.	SAN FRANCISCO, Calif.
BETHLEHEM, Penna.	SCHENECTADY, N. Y.
BLOOMSBURG, Penna.	SHEBOYGAN, Wis.
CAMDEN, N. J.	WASHINGTON, D. C.
CHICAGO, Ill. (W. Southwest)	WATERBURY, Conn.
HOUSTON, Texas	WYOMISSING VALLEY, Penna.
LANSING, Michigan	
LOS ANGELES, Calif.	COLNE VALLEY, England
SAN DIEGO, Calif.	RECIFE, Brazil

FOND DU LAC, Wis.

COMBUSTION ENGINEERING—SUPERHEATER, INC.

FLASH DRYER DIVISION

1315 North Branch Street, Chicago 22, Illinois

Western Office: 560 W. Sixth, Los Angeles 14, Calif. Eastern Office: 200 Madison Ave., N. Y. 16, N. Y.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT

(Continued from page 112A)

As Will Rogers used to say, "all I know is what I read in the papers." —and the other day I read where the "cautious, conservative and brilliantly staffed Massachusetts Institute of Technology (take a bow Eliassen and Sawyer) has perfected a new process whereby sea water can be made fresh for all domestic, irrigation and industrial uses, in any amout required.

A fellow by the name of Walter Juda heads the group which has a secret synthetic membrane through which they pass electricity and sea water at the same time. Result: two volumes of fresh water and one volume of strong brine for each three volumes treated. Chief cost; electricity —What won't they think of next. Now all they have to do is pipe that fresh water from the sea to the hinterlands far away where water is short.

* * *

You can now get the story of water, and its effect on civilization, in comic book form for a mere ten cents. Write the Electric Water System Council of the Plumbing and Heating Industries Bureau, 35 East Wacker Drive, Chicago 1, Illinois.

* * *

"O wad some power the giftie gie us, to see oursels as others see us" wrote Poet Bobby Burns. Bobby didn't have a Harry Faber to sit behind him at the NESIWA meeting and sketch how he looked from the back—But I did—

* * *

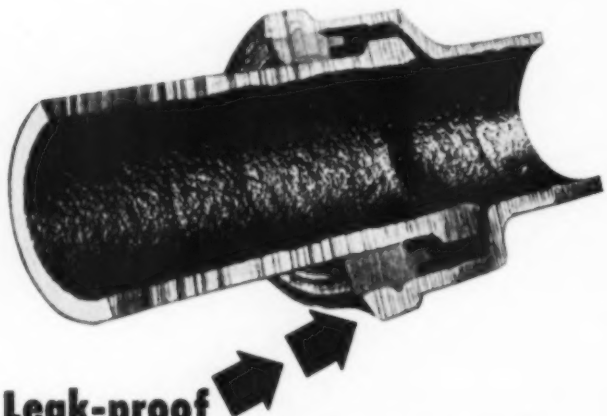
Now, just before the full bloom of spring is upon us and while a few nasty days are still around, seems a good time to remember the boat ride from Boston to Provincetown, Mass., during the NEWWA meeting last September.

I shall never forget that pleasant, partially sunny afternoon, boarding the Boston Belle at Foster's Wharf, the smell of the sea, the recorded voice of Edward Rowe Snow pointing out the historic landmarks as we threaded our way out of Boston Harbor, Governors Island, Deer Island, America's first lighthouse, the Boston Light ——. Then out onto the bay, past Minot's Light which at night flashes in code "I love you"—the soft breeze in our faces, the slight ground swell beneath us, the gulls, the whale (thar she blows) and friends.

Less than three hours later, the Pilgrim Memorial Monument on Cape Cod was visible and within another hour we were at Provincetown at the tip of the encircling arm of Cape Cod. It's an interesting and odd city, quaint in its old fashioned houses set so close to the narrow street, but modern in its greedy atmosphere of the carnival and the barkers for the honky tonks to attract the sightseers' dollar.

The food we ate was good but slow in coming and we just made it back to the boat in time. The trip back was sheer delight, with the moon rising out of the ocean and the shore lights a twinkling pattern of sparkle and distant brilliance. And, of course, there were the delightful companions: The Reg Hayes, the Dan Saunders,

(Continued on page 117A)



Leak-proof joints WITHOUT CAULKING... with ATLAS Tegul-MINERALEAD

NO CAULKING means that you do not depend on the workmanship of a man doing the caulking. With ATLAS Tegul-MINERALEAD, cast iron pipe joints can be poured and forgotten; permanently protected by a bond that renews itself under heavy stress.

Tegul-MINERALEAD® offers economy in material and labor costs, but it also offers economy in permanence . . . not requiring maintenance. Tegul-MINERALEAD contains no soluble salts to leach out and weaken the joint . . . no iron filings.

SEND FOR BULLETIN MIO-1A

OTHER ATLAS PIPE JOINTING MATERIALS

For Sewers: GK,® Slipjoint GK® and JC-60.
For Cast Iron Water Pipe: Hydrorings®

ATLAS JOINTING COMPOUNDS
...a permanent bond

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MERTZTOWN, PENNSYLVANIA
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MORSE BOULGER

★ Mechanically-Stoked Incinerators

★ Rotating Hearth and Multiple Hearth Furnaces

★ Cell Type Incinerators

Order "Experienced" Units

Morse Boulger offers a line of Mechanically Stoked Incinerators and Hearth Furnaces to handle all types of municipal refuse, sewage sludges and industrial wastes. They are *engineered* for each job with a background of 60 years of experience in the field of incineration.

Included in the more recent Morse Boulger projects, either already in operation or currently being engineered or constructed are those on the accompanying list.*

Incineration is the *Modern* way to dispose of refuse, garbage, rubbish, sludges and wastes. It is practicable for *any* community regardless of size. It is suitable for many industrial wastes. If you have any such problem, our engineers will be glad to work out with you and your consulting engineers the best method and the details.

*NOTE: In addition to the communities now operating or installing Morse Boulger Mechanically Stoked Incinerators as listed, scores of cities and towns are disposing of their refuse in Morse Boulger Cell Type Incinerators.

Recent Morse Boulger Projects Mechanically Stoked Incinerators and Hearth Furnaces

J. T. Baker Chemical Co.
Phillipsburg, N.J.
Rotating Hearth Furnace for handling filtered organic sludge.

Several Defense Plants
"classified projects"

Fort Worth, Texas
2 units for handling city refuse; approx. 250 tons.
Architect-Engineer: Wyatt C. Hedrick

City of Los Angeles
100 ton unit for city refuse; provision for second unit.
Engineers: Greeley & Hansen, Chicago

Mayaguez, Puerto Rico
60 ton unit for city refuse.

Gloucester City, N.J.
60 ton unit for garbage and rubbish, with upper rotary hearth for sewage sludge.
Engineers: Andrews & Gieseke, Philadelphia

The Atlantic Refining Co.
Point Breeze, Philadelphia
Large unit with waste heat recovery system for handling filter cake from waste water treating plant.

Esso Standard Oil Co.
Baltimore, Md.
For handling tank bottoms, liquid wastes, and general refinery refuse.

City of Saginaw, Mich.
Multiple hearth furnace for incineration of raw primary sewage sludge.
Engineers: Hubbell, Roth & Clark, Detroit

Merck & Co., Inc.
South Danville, Pa.
4 different units: two multiple hearth units, one for general rubbish and a waste solvent destructor.

Washington Suburban Sanitary Commission
Lyttonsville, Md.
75 ton unit for community garbage and rubbish.

Pomona, California
2 units totalling 225 tons for garbage and rubbish.
Engineers: Black & Veatch, Kansas City, Missouri

Lawrence, Mass.
2 units totalling 300 tons for garbage and rubbish.
Architects: Ashton, Huntress & Pratt
Engineers: Metcalf & Eddy

Gretna, Louisiana
2 units totalling 100 tons for garbage and rubbish.
Engineers: Alvin E. Hotard and Carl Schneider

Hempstead, N.Y.
4 units totalling 672 tons for garbage, rubbish, etc. Will be largest mechanically stoked municipal incinerator in the United States. Includes waste heat boilers, dust collectors, and mechanical ash removal.
Engineer: Henry W. Taylor

Merck & Co., Inc.
Rahway, N.J.
90 ton unit for general refuse.

HEAVY-DUTY INCINERATION
MORSE BOULGER DESTRUCTORS

MORSE BOULGER DESTRUCTOR CO.

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Representatives in Principal Cities

Which filter pioneered continuous mechanical sludge dewatering, making the elimination of sludge beds practical and economical?

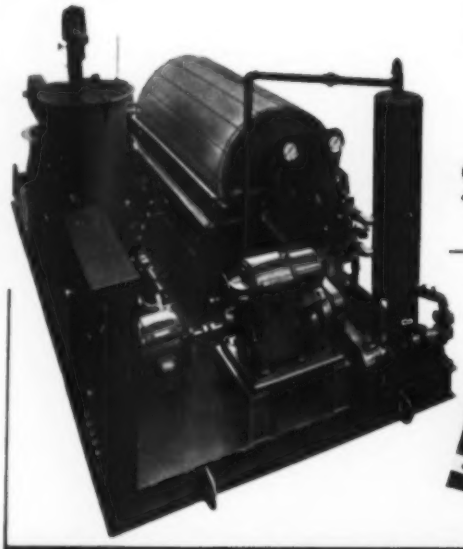
Which filter carried mechanical sludge dewatering through the inevitable "trial and error" period to its present high state of adaptability and effectiveness?

Which filter also appeared on the market first as a 'packaged' unit, such as illustrated?

Which filter can show the greatest amount of varied filtration experience including industrial waste handling?

Which filter has the most experienced engineering staff back of it, experienced in the field of continuous sludge dewatering?

It's the Oliver Filter . . . the sure bet for any city or town wanting a seasoned, well-experienced filter for dewatering its sewage sludges.



OLIVER SLUDGE DEWATERER

Send for Bulletin No. 219 which gives details of the Oliver Mechanical Sludge Dewaterer. Small communities particularly will be interested in the "Packaged" Oliver Filter, such as illustrated.

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Dorr-Oliver S.a.R.L. Milano
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HAWAIIAN ISLANDS
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clarify wastes at least cost...

the Cyclator®

meets disposal requirements best...

1 Because the Cyclator combines recirculation for more complete clarification and faster settling with mechanical thickening for maximum sludge compaction... you gain greatest B.O.D., oil and suspended solids reduction at considerably higher flow rates than in "old style" disposal plants.

2 Because the Cyclator increases purification rates and eliminates the need for large chemical mixing, coagulating and settling basins, you save space... save on first costs.

3 Case histories of Cyclator operation dramatically

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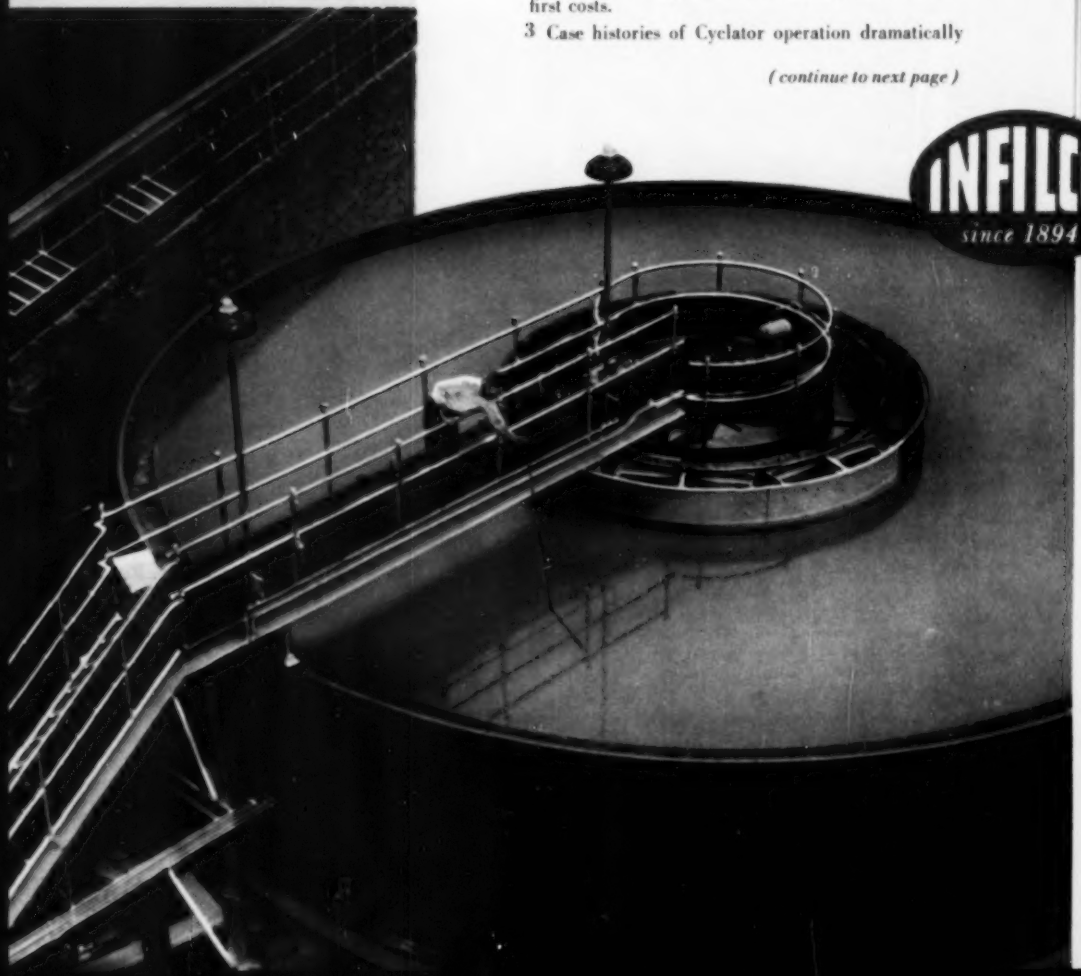


INFILCO
since 1894

(continued from preceding page)

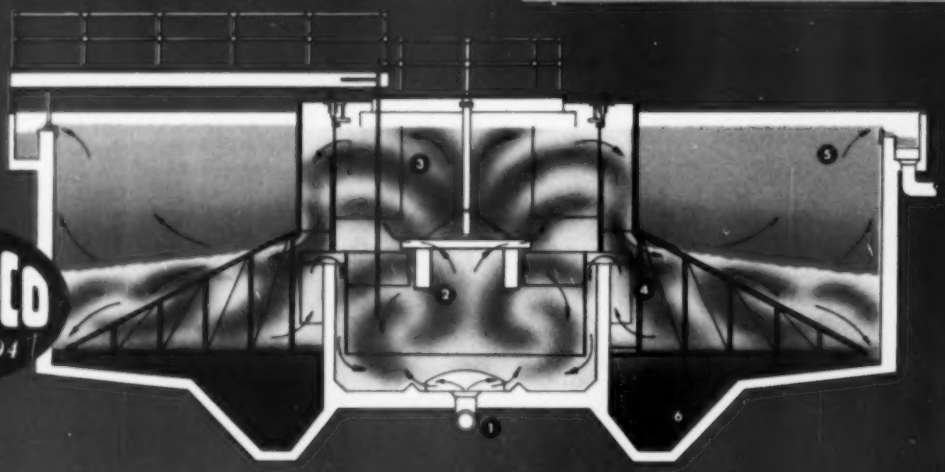
illustrate the vital point that the Cyclator will clarify wastes to your local requirements at least cost. Write for Bulletin 850A – containing data and case histories which show how the Cyclator exceeds expectations for processors everywhere – North America, South America, Europe.

INFILCO INC. ★ *Tucson, Arizona*

Here's how the Cyclator EXCEEDS waste disposal requirements

- ★ Space-savings up to 80% in comparison to "old-style" treatment plants.
- ★ By-product recovery and water re-use pay for Cyclator operation in many cases.
- ★ Removes suspended and colloidal solids, oils and toxic compounds rapidly and efficiently.
- ★ Throughput is extremely high because chemical feeding, recirculation and mechanical thickening are perfectly balanced in a single basin.
- ★ Reduces chemical costs because most efficient mixing is attained with recirculation.
- ★ Effluent purified to the degree required to meet pollution control regulations.

INFILCO *since 1894*



"EXPLAIN-MORE" DIAGRAM

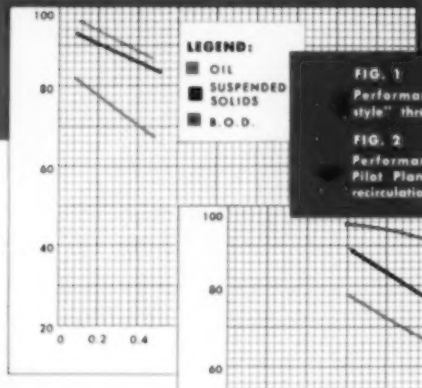
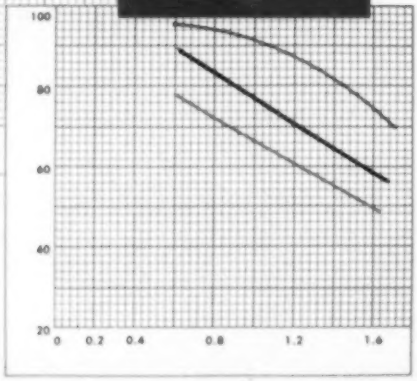


FIG. 1
Performance of "old-style" three-basin plant

FIG. 2
Performance of Infilco Pilot Plant with recirculation

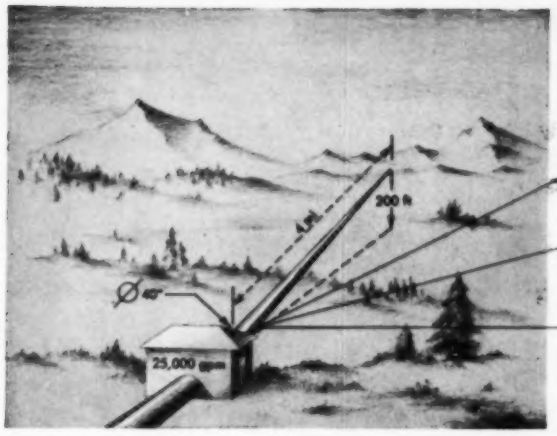


TAKE A LOOK AT PROCESS SAVINGS—

Here's a recent pilot plant study. An Infilco pilot plant was installed in parallel with a treatment plant with separate mixing, flocculating and sedimentation basins.

Both plants treated oil-bearing wastes. Alum and activated silica were used as the coagulants. Figure 1 shows that the three-basin plant operated at a rise rate of only 0.2 gpm per square foot for about 95% oil removal. Slightly higher removal was gained with the Infilco plant and at a rise rate of 0.6 gpm!

The result: two 100-foot diameter Cyclators were installed by a large Eastern refinery to treat waste at 3700 gpm. Process savings like this are typical of Cyclator installations. When you need facts for waste disposal at least cost, ask for Infilco's specialized experience ... there's no obligation for preliminary planning.



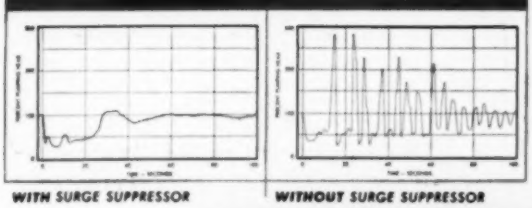
250 feet of head

525 feet of head

975 feet of head

?

CAN YOU PICK THE CORRECT ANSWER?



WITH SURGE SUPPRESSOR — WITHOUT SURGE SUPPRESSOR

● **Here is the problem:** Estimate how high total pressure head could rise from surge if power failure brought the pump in this system to an abrupt stop.

25,000 gallons per minute are being pumped up an elevation of 200 feet in a total pipeline length of 4 miles. Pumping head is 250 feet. Pipe diameter is 40 inches. A check valve is used to stop backflow through the pump.

Make your guess, then here is the answer

Total pressure head could rise as high as 975 feet. Inertia of the upward moving column of water builds up great potential energy. As the water settles back against the check valve, a succession of dangerous pressure waves occurs, often sufficient to burst the pipeline.

THE PELTON SURGE SUPPRESSOR

affords positive protection against this ever present danger — protection that no other valve gives.

Either current stoppage or pressure build-up actuates the **PELTON** Surge Suppressor. This quick-opening valve anticipates return surges and dissipates them by by-passing water around the pump; then it slowly closes as the pressure waves cease.

Lower pipeline costs can more than pay for a **PELTON** Surge Suppressor. Extra weight is eliminated because the pipe need not be designed with large safety factors in anticipation of high surge pressures. The possibility of line failures and interrupted service is greatly decreased.

Installations needing protection occur wherever water is pumped to a higher elevation either through a long pipeline or at high velocity. **PELTON** Surge Suppressors can be furnished to protect waterlines of any size handling service pressures up to 800 p.s.i.

Send us your problem and include pipeline profile. Our engineers will make recommendations without obligation.

The PELTON WATER WHEEL Company

Subsidiary of Baldwin-Lima-Hamilton Corporation

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"Every individual connected with water purification or sewage works should subscribe to this publication. I have introduced it to a host of friends in this field"

Testimonials such as this from subscribers to WATER & SEWAGE WORKS really tell the story. The man who reads and uses the magazine as an aid in his work knows how much it will benefit other workers in the field.

The great REFERENCE & DATA issue alone is worth more than the yearly subscription rate. In it you will find formulae, charts and illustrations covering information not obtainable in any other one source.

Supply of 1952 REFERENCE & DATA number is limited. If you are not a subscriber send your order today!

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- *If you are interested in the water field only you get all the authoritative data on this subject.*
- *If you are interested in sewage problems only you are kept fully informed and given much help in this field.*
- *If you are interested in both subjects you get all the information in this one monthly magazine.*

(Continued from page 114A)

(Council Bluffers), the Karl Manns, the Bob Orths, the Leland Carltons, the Roy Evans, the John Stewarts, the Karl Kennisons, the Tom Camps, the Sid Anthonys, the Don Calderwoods, and dozens more to make up 320 in all.

Thanks to Bill Brenchick of J-M for scheduling such a pleasurable interlude and ordering perfect weather. —What's in store for next September, Bill?

* * *

Attention—All Council Bluffers—The annual meeting will be held in the room of Dan Saunders on Thursday midnight, May 8, by order of the President Samuel Newkirk and Vice President Tina La Due. Attest. Doc Symons, Secy.

* * *

Well—"Gotta go now"—see you in K. C.—and DON'T forget the Federation meeting in New York, next October 5-9.

V.T.Y.—Doc

Apprentice Training With Lynchburg Foundry Co.

The Lynchburg Foundry Company takes pride in seldom going outside its own plants to find skilled workers, even in the face of expanding operations, which have doubled its work force in the last ten years.

The key to this accomplishment may be found in the wording of a Certificate of Meritorious Service recently awarded this Company by the Commonwealth of Virginia:

". . . . . that the Lynchburg Foundry Company has made a valuable contribution to industry in the community, and the State. Such contribution is the direct result of interest and foresight shown in the training of its craftsmen through apprenticeship."

Since 1930 the Company has been offering to selected high school graduates a four-year course of individual instruction in the various trades of foundryman, machinist, electrician, and patternmaker. The first objective of such a course is an adequate supply of journeyman workers. This is being realized, and it has also been found that many of the supervisory posi-

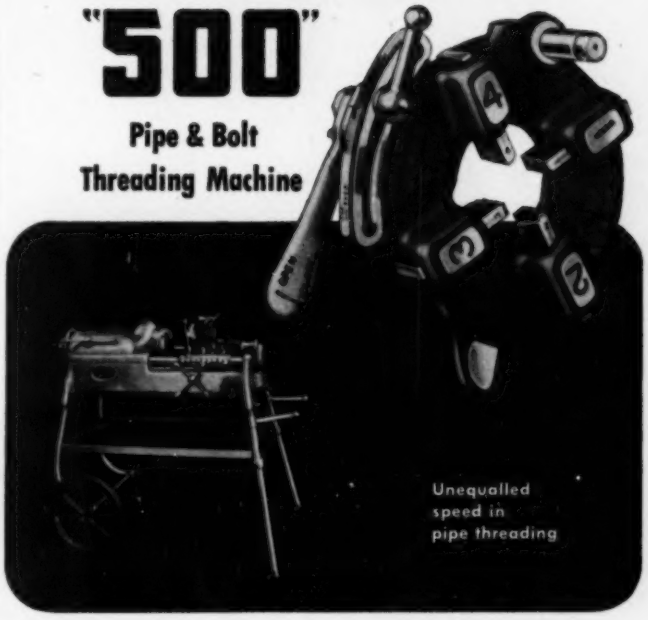
Exclusive New Quick-Opening Quadritype Die Heads

ON THE NEW

RIDGID

"500"

Pipe & Bolt Threading Machine



New "500" Quadritype Die Head can be instantly adjusted from 1" to 2" regardless of position of quick-opening lever —and without removing dies or die head from machine

★ Also improved Dualtype Die Heads, one for ¼" and ⅜", one for ½" and ¾", same instant size change *right in the machine.*

★ Also separate Monotype Die Heads available, ⅛" to 2", bolt die heads, ¼" to 2".

★ All tools in the "500" thread, cut, ream independently, and right up to chuck, swing out of way when not in use.

★ With a score of other sensational new features! See the new RIDGID "500" at your Supply House.

THE RIDGE TOOL COMPANY • ELYRIA, OHIO

★★★ RIDGID Work-Saver Pipe Tools ★★★

tions have been filled by graduates of the apprentice school. Such results led Mr. Henry McWane, President of the Company, to state: "I know of no investment that has paid greater dividends than our apprentice program".

Each apprentice is required to attend a class in related instruction six hours each week for forty weeks per year. After a review in arithmetic the trainee is given instruction in algebra, geometry, trigonometry, logarithms, blueprint reading, and engineering drawing. He is also required to subscribe to a correspondence course of trade subjects pertinent to the work he is pursuing. A portion of each six-hour instruction period is allowed for supervised study of this course.

Lynchburg Foundry Company Graduates completing their apprenticeship during 1951.

The Company believes that a general knowledge of the entire operation is necessary to efficient work in any one department, so the trainee is scheduled for various lengths of time in other departments during the apprentice period.

Each department head is responsible for the training within his supervision, although in some departments there is an apprentice instructor whose duty is to instruct the trainee in correct work processes and regulate his movement to diversified jobs and departments.

Each year the graduates are honored with a dinner and graduation exercises to which their families and Company friends are invited.

In 1945, at an American Foundryman's Association meeting in Chicago, Mr. Max Kuniansky, Executive Vice-President and General Manager of the Lynchburg Foundry Company, made the following statement: "The foundation of an industry rests upon men, and its future depends on its capacity to develop men. We must face the issue clearly and resolve to do the job of attracting the proper men and developing them in our industry."

These are not idle words at the Lynchburg Foundry. In addition to the apprentice program, the Company has training for college graduates, supervisors, and workers on-the-job. The programs are all results of management's belief that no industry is built on machines; it is built on men.

Cities Lose Test Case On Water Rates

The State of Texas Supreme Court recently ruled that a city can charge higher rates on water and sewage utilities to persons living outside city limits only if the service actually costs more. The court was split 5 to 4 on a test case from the city of Texarkana.

The decision stated that Texarkana's rate ordinance is void unless it can prove "there is some reasonable basis for the difference" in rates inside and outside the city. It called for a new trial on this point.

Impact Insurance Against
1—LOSS OF FIRE PROTECTION.
2—EXCAVATION AND PAVEMENT REPLACEMENT.
3—COSTLY REPAIRS INVOLVING MAJOR HYDRANT COMPONENTS.
4—FLOODING.
The Smith Protectop Hydrant is designed to permit rapid return to service at minimum cost when a Hydrant is damaged as a result of a traffic accident.
The Protectop Hydrant Standpipe and Valve Stem are equipped with Special Couplings located just above the ground. The Couplings withstand operating pressures and ordinary impact with an ample factor of safety. Under excessive impact occasioned by traffic accidents the Couplings fracture at the design points thus minimizing the damage and permitting speedy return to service at low cost.
All Smith Hydrants are equipped with Compression Type Valves which definitely eliminate flooding since the line pressure holds the Valve against its seat in the closed position.
Write for details.
38
THE A.P. SMITH MFG. CO.
EAST ORANGE, NEW JERSEY

A minority wrote that Texarkana was entitled to make its own terms and conditions in supplying water and sewage services to North Texarkana residents.

The ruling will affect many Texas cities having growing populations outside municipal boundaries. An official of the League of Texas Municipalities said most cities charge 25 to 50 per cent higher rates for water and sewage service to non-residents.

Texarkana's ordinance called for rates outside the city to be 50 per cent higher on water and 100 per cent higher on sewage services.

The majority opinion claims that the city cannot discriminate in fixing rates since citizens outside city limits have no other place to get water and sewage service. It stated, "this decision is certainly in line with well-established principles of public utility law."

W. B. Harman

J. M. Pharr

Harman Appointed Manager Newport News Waterworks

Pharr Appointed Asst. Genl. Mgr.

W. B. Harman, former assistant manager and lately acting manager, has been appointed general manager of the Newport News (Va.) Waterworks, which is a municipally owned system operated under a Waterworks Commission as a private water utility would be operated. He succeeds the late Eugene F. Dugger, who held the post from the end of World War I until his retirement about a year ago, due to ill health.

Mr. Harman, a native of Richmond, Va., has been associated with the Newport News Waterworks since 1920, when it was still a privately owned utility. In 1937 he became assistant general manager.

J. M. Pharr, former chemist and bacteriologist in charge of water purification, becomes assistant general manager. He became associated with the water utility in 1934. A resident of the Newport News area since 1918, he was graduated by the Va. Polytechnic Institute in 1932 as a B.S. in Chemical Engineering. A year later he won the M.S. degree. He emerged from World War II as a major and was discharged from active duty with the rank of lieutenant colonel in the reserves.

Mr. Pharr will have charge of all production, including purification plants and the several pumping stations.

Messrs. Harman and Pharr have long been active in the Virginia Section of A.W.W.A., Mr. Harman being a former Chairman of the Section. He has just lately been appointed a member of the National Production Authority's recently created Advisory Committee representing the Water and Sewage Works Industry countrywide. This thirteen member committee of national scope is advising N.P.A. and assisting in development of a proposed "M" Order for operation of the Water Resources Div. of N.P.A. which has done a remarkably effective job considering its lateness of getting started as a component of N.P.A. under the Controlled Materials Plan.

No Guesswork For Sidewalk Supers

In London, Ont., the Public Utilities Commission will mark its jobs

...if she knew what Centriline means to her

Each time this lady, and millions like her, turns on her water faucet, she benefits from the Centriline process. In cities where water pipes and mains have been Centrilined, there will be no loss in pressure, or water contamination due to corrosion and tuberculation . . . no increase in water bills for her due to increased pumping and maintenance costs . . . no inconvenience due to torn-up streets. Yes, this lady *should* know about Centrilining . . . and so should *you*. The Centriline process thoroughly cleans pipelines *in place* up to 144" in diameter—coats the walls centrifugally with strong cement-mortar and trowels it to a smooth even surface . . . strengthening the pipe . . . making it better than new. Corrosion is prevented, leakage is stopped, flow capacity improved. Write for your copy of Centriline's new booklet describing this time proven process.

CEMENT-MORTAR LININGS FOR PIPES IN POSITION

2,298,688 FEET OF EXPERIENCE

CENTRILINE CORPORATION

A subsidiary of Raymond Concrete Pile Co.

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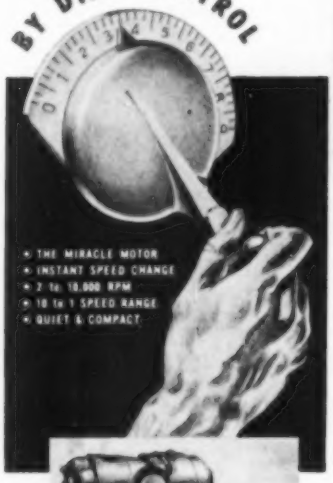
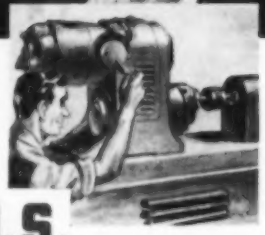
Branch Offices in Principal Cities of United States and Latin America

ON THE WEST COAST, WRITE PIPE LININGS, INC., P. O. BOX 3428, TERMINAL ANNEX, LOS ANGELES, CALIFORNIA

ANY RPM

BY DIAL CONTROL





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ANY RPM at your finger tips. The U. S. Varidrive gives magic speed control to your machine or equipment. All-in-one unit, replaces motor, speed changer and gear box. ¼ to 30 hp. Mail Coupon for Bulletin.

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Send 16-page colored Varidrive Bulletin.
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City_____
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with signs telling "sidewalk superintendents" what's going on. Example: when a crew goes out to fix a water main, the first thing a crew does is to put up a sign reading *servicing London's 260 miles of water mains.* The commission plans to have the signs include details which will answer all types of questions.

H. D. Crippen

F. A. Michel Jr.

Crippen Made Vice-President

Michel Made Eastern Manager of Water and Sewage Works

Huston D. Crippen, until now Eastern Manager for Gillette Publications has been made a vice president of *Water and Sewage Works* magazine.

Mr. Crippen prior to his association with the Gillette Publishing Co. was a District Manager for Esquire Magazine, and prior to that was vice-president of Teck Publishing Co. He saw service in World War II as a Lieut. Colonel.

Fred A. Michel Jr. succeeds Mr. Crippen as Eastern Manager for *Water and Sewage Works.* He has been connected with Gillette Publications since 1946 as sales representative. A Bucknell graduate he entered the U.S. Army as a private in World War II, saw action in Europe and in the Aleutian Islands, and rose to the rank of 1st Lieutenant.

Mr. Michel will continue to represent *Water and Sewage Works* in the New England States and New York State.

Excerpts from Purdue's Sanitary Engineering News*

EGYPT—"Water—(as usual)—is the Key to Egyptian history. Without the Nile Egypt would all be a sandy waste. Even now 96 per cent of its fertile land is close to the River, as are the homes of nearly all Egypt's seventeen million people."

In terms of its elements, dry garbage combustibles average 55% carbon, 7% hydrogen, 35% oxygen and 3% nitrogen.

*Edited by Prof. Don E. Bloodgood.

(Continued on page 122A)

3way dependability is built into ALL EDDY Fire Hydrants

AVAILABLE WITH BELL CONNECTION (shown) or MECHANICAL JOINT CONNECTION with or without AUXILIARY VALVE

Since 1849 EDDY For Long Service

1. **IN CASE OF FIRE** — dependable, smooth operation . . . clear, large waterways . . . insure plenty of water. Hydrants open fast and easily *with* the pressure . . . and close without water hammer.
2. **IN CASE OF ACCIDENT** — stem held in place below main valve means no water loss due to a bent stem. One man can easily remove all operating mechanism for inspection or repairs.
3. **FREEZE PROOF** — Eddy's positive drip action automatically drains hydrant barrel of all water when hydrant is closed . . . safeguards hydrant against freeze-ups.

EDDY VALVE COMPANY
A Subsidiary of James B. Clow & Sons
WATERFORD, NEW YORK

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WATER & SEWAGE WORKS READER SERVICE

READER SERVICE CARDS HOW TO USE THEM

Please fill out a separate coupon for each item on which you desire information. This will greatly facilitate handling.

Key number is at head of each new product, item of equipment, catalog or bulletin, described in this issue.

Enter key number in box.

Please PRINT your name and title, company or department name, and your address

NOTE—

These cards are to be used only for items described in THIS ISSUE

WATER & SEWAGE WORKS

Will see that you receive information desired.

Prevent scale formation,
Prevent red or black water,
Control corrosion,
Stabilize water in municipal and industrial systems

Calgon Threshold Treatment for municipal and industrial water problems proves itself by overcoming such serious problems as those listed above. Threshold Treatment is a simple and economical method of controlling corrosion, preventing lime scale, eliminating discolored water, reducing tuberculation, whether from corrosion or precipitation of dissolved iron or manganese.

We would like to discuss your problems with you, and tell you just what Calgon can do for you. For information, write, wire or phone today.

*T. M. Reg. U. S. Pat. Off.

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BUROMIN
CALGON

calgon, inc.

A SUBSIDIARY OF
HAGAN CORPORATION

HAGAN BUILDING
PITTSBURGH 30, PA.

(Continued from page 120A)

After-dinner speaking is the art of saying nothing briefly.

The per capita water consumption in New York City is two and one-half times that of London.

The municipal ordinances of Sturgis, Michigan, prohibit the discharge of industrial wastes outside of the pH range of 5.0 to 10.0.

Ground water is the only practical source of public water supply for most of the cities and towns in Delaware. Of the 31 water supply systems listed for Delaware by the U.S. Public Health Service, 29 obtain water from wells.

Superchlorination, chlorine dioxide, and activated carbon help to overcome the taste and odor problem in the heavily polluted river supply of Lawrence, Kansas.

Oil companies use a scraping device forced by hydraulic pressure through long pipe lines to clean them. They now fit the scraper with a small piece of radio-active cobalt, so that if the scraper gets stuck, its exact location can be found by a radiation detector.

The most effective reagent for removing silica by the hot process from boiler water is magnesium oxide which eliminates the silica by a process involving initial absorption followed by compound formation.

The annual growth of the United States is estimated to be 1.5 million.

Ray Bender of Hays, Kansas, controls filter flies on his two 90 foot sprinkling filters by the application of four gallons 5% D.D.T. solution sprayed over the stone, distributor arms, inside and outside filter walls and ground around the filters for a distance of 15 feet. The application is made in April, June and August.

You cannot teach a man anything; you can only help him find it within himself.

An improved method for the determination of volatile acids in sewage sludge has been developed by Heukelekian and Kaplovsky.

There are 92 filtered water supplies in Australia, but the bulk of towns use natural untreated water.

Nearly 1,000 treatment plants were under construction in 1949 in the United States. Thirteen projects for sewage treatment and sixteen projects for industrial waste were Indiana's share.

Estimates show that a family man who dies between the ages of 35-44 loses about $25,000 in net future earnings during his normal life expectancy remaining.

Come by and Say Hello!

M&H BOOTH

A. W. W. A. CONVENTION EXHIBIT

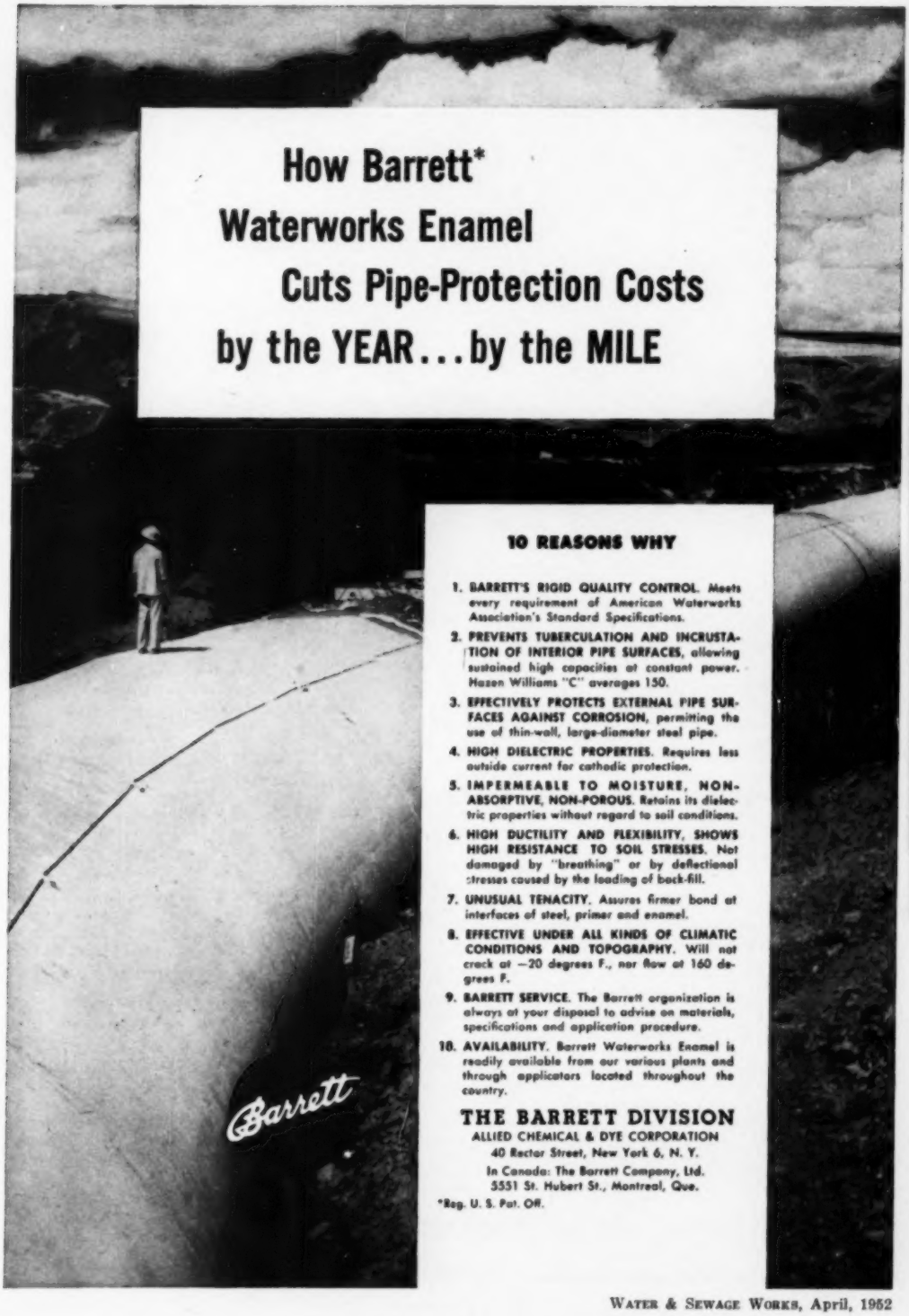
KANSAS CITY AUDITORIUM—MAY 4-9, 1952

We look forward with keen pleasure to the A.W.W.A. Convention at Kansas City, Missouri, May 4-9, 1952. It is going to be a big meeting—and a good opportunity for us to meet old friends again and swap a few good stories.

Of course, if you should be interested in a wee bit of up-to-date information on Valves or Hydrants (just in case, of course), we might be able to satisfy your curiosity. But you will not need to "talk shop" to be welcome. Come by the M&H Booth.

M&H PRODUCTS FOR WATER WORKS • FILTER PLANTS INDUSTRY • SEWAGE DISPOSAL AND FIRE PROTECTION

"An'—didya know mishter they're talking about closin' down our wonnerful distillery."



How Barrett* Waterworks Enamel Cuts Pipe-Protection Costs by the YEAR...by the MILE

10 REASONS WHY

1. **BARRETT'S RIGID QUALITY CONTROL.** Meets every requirement of American Waterworks Association's Standard Specifications.
2. **PREVENTS TUBERCULATION AND INCRUSTATION OF INTERIOR PIPE SURFACES,** allowing sustained high capacities at constant power. Hazen Williams "C" averages 150.
3. **EFFECTIVELY PROTECTS EXTERNAL PIPE SURFACES AGAINST CORROSION,** permitting the use of thin-wall, large-diameter steel pipe.
4. **HIGH DIELECTRIC PROPERTIES.** Requires less outside current for cathodic protection.
5. **IMPERMEABLE TO MOISTURE, NON-ABSORPTIVE, NON-POROUS.** Retains its dielectric properties without regard to soil conditions.
6. **HIGH DUCTILITY AND FLEXIBILITY, SHOWS HIGH RESISTANCE TO SOIL STRESSES.** Not damaged by "breathing" or by deflectional stresses caused by the loading of back-fill.
7. **UNUSUAL TENACITY.** Assures firmer bond at interfaces of steel, primer and enamel.
8. **EFFECTIVE UNDER ALL KINDS OF CLIMATIC CONDITIONS AND TOPOGRAPHY.** Will not crack at −20 degrees F., nor flow at 160 degrees F.
9. **BARRETT SERVICE.** The Barrett organization is always at your disposal to advise on materials, specifications and application procedure.
10. **AVAILABILITY.** Barrett Waterworks Enamel is readily available from our various plants and through applicators located throughout the country.

THE BARRETT DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 Rector Street, New York 6, N. Y.
In Canada: The Barrett Company, Ltd.
5551 St. Hubert St., Montreal, Que.

*Reg. U. S. Pat. Off.

Meetings Scheduled

(Continued from page 109A)

Oct. 20-24—Cleveland, Ohio
AMERICAN PUBLIC HEALTH ASSOCIATION. Sec'y, Mrs. W. R. Walsh, A.P.H.A., 1790 Broadway, New York, N.Y.

Oct. 23-25—Atlantic City, N.J. *(Hotel Madison)*
NEW JERSEY SECTION A.W.W.A. Sec'y, C. B. Tygert, Box 178, Newark 1, N.J.

Oct. 23-25—Mason City, Iowa *(Hanford Hotel)*
IOWA SECTION A.W.W.A. Sec'y, H. V. Pedersen, Municipal Bldg., Marshalltown, Iowa.

Oct. 28-31—Pasadena, Calif. *(Huntington Hotel)*
CALIFORNIA SECTION A.W.W.A. Acting Sec'y, Lee Streicher, Metropolitan Water District, 545 Cloverleaf Way, Monrovia, Calif.

Oct. 29-31—Washington, D.C. *(Wardman Park Hotel)*
CHESAPEAKE SECTION A.W.W.A. Sec'y, Carl L. Lauter, 6955 33rd St., Washington, D.C.

Nov. 5-7—Old Point Comfort, Va. *(Chamberlin Hotel)*
VIRGINIA SECTION A.W.W.A. Sec'y, W. H. Shewbridge, Regional Engr., 708 State Office Bldg., Richmond, Va.

Nov. 10-12—Hendersonville, N.C. *(Hotel Skyland)*
NORTH CAROLINA SECTION A.W.W.A. Sec'y, E. C. Hubbard, State Board of Health, Raleigh, N.C.

Nov. 16-19—Pensacola, Fla. *(Hotel San Carlos)*
ALABAMA-MISSISSIPPI SECTION A.W.W.A. Sec'y, C. W. White, State Board of Health, 519 Dexter Ave., Montgomery 4, Ala. (Joint Meeting). FLORIDA SECTION A.W.W.A. Sec'y, M. R. Boyce, 504 Pennsylvania Ave., Clearwater, Fla.

Dec. 4-6—Havana, Cuba
CUBAN SECTION A.W.W.A. Sec'y, L. H. Daniel, Baratillo 9, Havana, Cuba.

Dec. 10—Winthrop, Maine
MAINE WATER UTILITIES ASSOCIATION. Sec'y, Earle A. Tarr, Winthrop Water District, Winthrop, Me.

No feature is more important in your chlorinating equipment than safety—and no feeder is safer than BUILDERS Visible Flow CHLORINIZER.

Chlorinizer is SAFE because its system is under vacuum from chlorine control valve to injector inlet, eliminating possibility of chlorine escaping into the operating room.

Chlorinizer is SAFE because inlet valve closes instantaneously with substantial spring-imposed force, if any condition exists which is not proper for safe operation, including failure of water supply or breakage of any part of the vacuum system.

Chlorinizer is SAFE because chlorine gas is automatically exhausted to exterior of building by simple flow-actuated relief valve, if vacuum is reduced below safe operating condition.

Chlorinizer is SAFE because water is prevented from entering vital parts of the mechanism because relief valve admits air to bell jar automatically to limit vacuum under abnormal conditions.

Chlorinizer is SAFE because it's simple . . . easy to understand . . . easy to operate and to keep in top operating condition.

For Bulletins 840-F2A, 840-F1A, and 840-JB, address Builders-Providence, Inc. (Division of Builders Iron Foundry) 350 Harris Ave., Providence 1, R. I.

BIF INDUSTRIES — BUILDERS PROVIDENCE Instruments — BUILDERS

Manufacturers & Equipment News

Proportioning Weir Tank

401

Omega Machine Co., Providence, R. I., has developed a line of Proportioning Weir Tanks for solutions or suspensions. These devices consist of a specially constructed tank incorporating a stilling chamber, and accurately machined rectangular weir, two outlet chambers and a flow splitter, so arranged that the total flow of solution or suspension to the two outlets can be readily divided into any proportion.

The flow splitter is graduated into percent of total flow, is instantly adjustable, and has no moving parts. It may be fitted with a pneumatic or electric operator and is ideal for controlling the flow of liquids or suspensions in proportioning systems or automatic pH control systems.

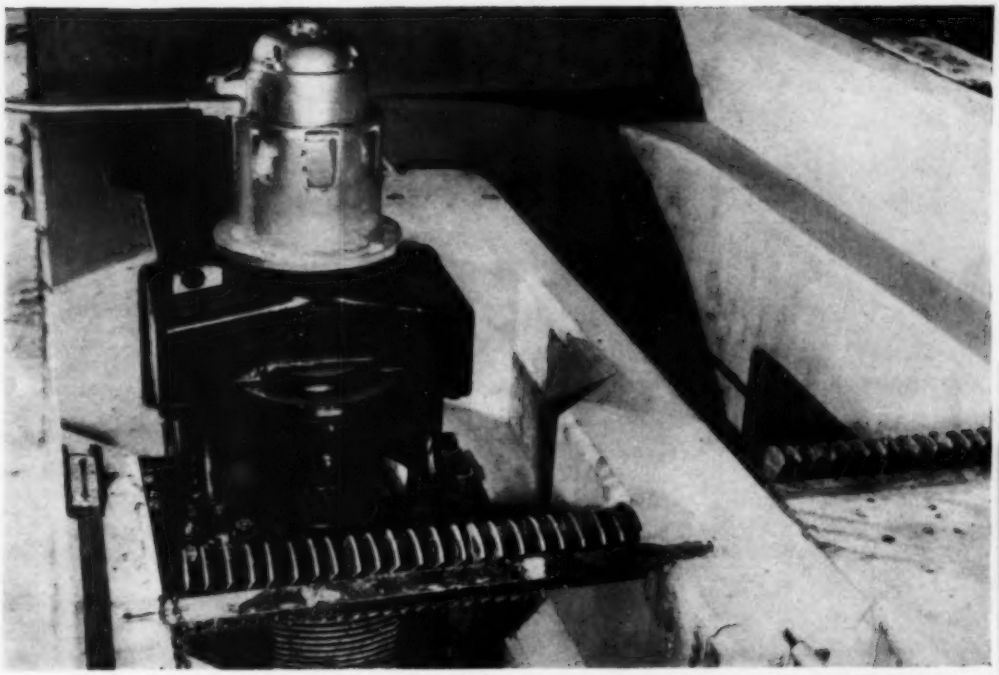
Changes in Fairbanks-Morse Sales Organization

Fairbanks-Morse & Co., Chicago, Ill., has announced the following changes in the company's sales organization:

J. A. Cuneo, formerly Manager of the Chicago Branch, has been promoted to the position of General Sales Manager.

(Continued on page 126A)

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.



WORTHINGTON COMMINUTOR IS EASILY INSTALLED TO HANDLE LARGE VARIATIONS IN FLOW like this one at the Madison-Chatham (N. J.) Sewage Treatment Plant. Maximum wet-weather flows are occasionally as high as five times the average design dry-weather flow. An overflow screen is installed on top of the comminutor to screen flows in excess of the comminutor's capacity. Screenings are later raked down into the comminutor during period of normal flow. The overflow screen makes the comminutor independent of the by-pass on right which may later be used as a channel for a second comminutor. Plant Superintendent is Edward P. Molitor.

Madison-Chatham, N. J., installation proves adaptability of Worthington COMMINUTOR

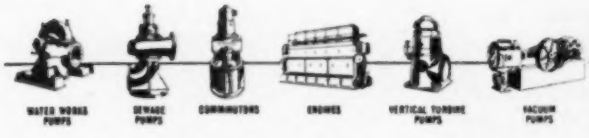
Typical example of the adaptability of the Worthington comminutor is the story of this installation at the Madison-Chatham Joint Meeting Sewage Treatment Plant in Chatham, N. J.

Engineers everywhere especially like the Worthington comminutor because:

- It can be readily installed in new or existing straight-flow rectangular channels.
- Cutter-racks are quickly removable for sharpening or replacement.
- It may be flooded without damage because it's protected by a mercury seal.

Worthington's public works specialists are ready to work with your community's engineer in solving screening problems—as well as other problems in sewage, water works, or municipal power generation. Write, stating details of problem or requesting Comminutor Bulletin W-2010-B3 to *Worthington Pump and Machinery Corporation, Public Works Division, Harrison, N. J.*

W-2.5



All Major Public Works Equipment Under One Responsibility

WORTHINGTON

Public Works Equipment

(Continued from page 124A)

H. L. Hilleary will continue as Assistant Sales Manager.

Milo C. Roy, formerly Manager of the Omaha Branch, has been appointed Manager of the Chicago Branch.

J. W. Wright, formerly Manager of the Diesel Sales Div., with headquarters in Chicago, has been appointed Manager of the Omaha Branch.

C. E. Dietle, formerly Diesel Dept. Manager of the Chicago branch, has been promoted to the position of Manager of the Diesel Sales Division.

W. B. Wylly, formerly Manager of the Houston, Texas Sub-Branch, has been appointed Manager of the Atlanta Branch.

L. A. Weom, formerly Manager of the St. Louis Branch, has been transferred to St. Paul where he has taken over the duties of Branch Manager succeeding A. C. Thompson who has retired after forty-five years of service.

Clifford J. Schroeer, formerly Diesel Department Manager of the St. Louis Branch, has been promoted to Manager of the St. Louis Branch succeeding L. A. Weom.

PROTECT YOUR WATER SUPPLY
with
ROSS AUTOMATIC VALVES

EFFICIENT REGULATION OF DISTRIBUTION PRESSURES IS A PROVEN METHOD OF CONSERVATION IN THE FIGHT AGAINST DIMINISHING WATER SUPPLIES

ROSS
1879

PRESSURE REDUCING VALVES

Maintains constant discharge pressure for all changes in rates of flow down stream.

BACK-PRESSURE VALVE

Maintains constant upstream pressure regardless of draft down stream.

COMBINATION
PRESSURE REDUCING AND BACK-PRESSURE VALVE

OTHER ROSS PRODUCTS

ALTITUDE VALVES • FLOAT VALVES • RELIEF VALVES
HYDRAULIC BOOSTER PUMPS
STRAINERS AND SPECIALTIES

Write for Catalog #50

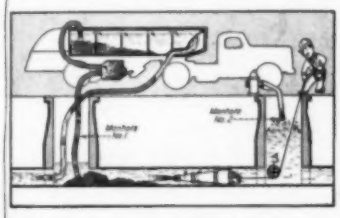
ROSS VALVE MANUFACTURING CO., INC.
4 OAKWOOD AVENUE——TROY, NEW YORK

Norcam Method of Sewer Cleaning

402

Southwestern Norcam Co. of Dallas, Texas, offers a unique method of cleaning sewers, in which a specially designed tank-truck and the novel Norcam Sewer Cleaner operate in combination.

One of the accompanying illustrations pictures the Norcam Sanitary Cleaning Unit as it appears on the streets during a sewer cleaning job. The other illustration reveals how the combination of tank-truck and Norcam Cleaner does the cleaning job from manhole to manhole.



The Norcam tank-truck, equipped with a pump, is stationed at the lower manhole. The suction hose is dropped into the manhole and the discharge hose, passing through a plug inserted in the sewer outlet, delivers into the downstream sewer. The Norcam Sewer Cleaner is then inserted in the sewer at the upper manhole and is propelled through the line by hydraulic head, obtained by bleeding a fire-hydrant into the manhole, or by other means injecting water into the manhole. The nozzle at the head of the cleaner creates the jetting and scouring effect which moves all deposits in the sewer to the lower manhole, from which it is sucked up into the tank-truck. Passage through the 2,000-gal. baffled tank on the truck allows the grit and debris to settle out and the effluent to be discharged into the downstream sewer.

Only about four feet of water or sewage is needed behind the cleaner unit to do the job. The cleaner can move forward only as fast as the grit and debris is jetted ahead of it, thus a single passage insures a thoroughly cleaned section of sewer.

(Continued on page 128A)

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

For Water Treatment . . .

SOLVAY
SODA ASH

For Water Problems . . .

SOLVAY
TECHNICAL
SERVICE

For Water Information . . .

SOLVAY
TECHNICAL
BULLETINS

Technical Literature Available on Request

Bulletin No. 5—Soda Ash
Bulletin No. 7—Liquid Chlorine
Bulletin No. 8—Alkalies and Chlorine in the Treatment of Municipal and Industrial Water
Bulletin No. 11—Water Analysis

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ALLIED CHEMICAL & DYE CORPORATION
40 Rector Street, New York 6, N. Y.

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Alkalies Chemicals
Since 1881

Caustic Soda
Caustic Potash
Chlorine
Potassium Carbonate
Nytron
Calcium Chloride
Sodium Bicarbonate
Specialty Cleansers
Sodium Nitrite
Soda Ash
Ammonium Bicarbonate
Para-dichlorobenzene
Ortho-dichlorobenzene
Monochlorobenzene
Methanol
Ammonium Chloride
Formaldehyde

(Continued from page 126A)

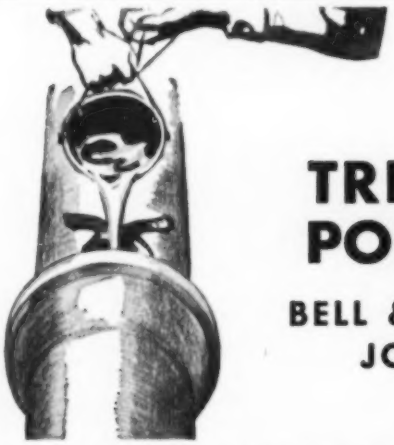
The debris accumulation in the baffled tank is disposed of by driving the truck to approved area for debris dumping. The feature most prominent in the Norcam method of sewer cleaning is its sanitary aspects, in which none of the material removed from the sewer reaches the street, the entire operation being an "enclosed" one.

The Southwestern Norcam method has been successfully used, on 6 in. to 48 in. sewers, and was extensively used in clearing choked sewers in Manhattan and Topeka, Kan., and at other points suffering damage during the 1951 flood.

Rockwell Advances Andrews to Sales Manager N.Y. District

Rockwell Manufacturing Co., Pittsburgh, Pa., has announced the appointment of W. S. Andrews as New York District Sales Manager. Due to the reorganization of the Company's sales structure into five regional areas, Mr. Andrews will succeed M. J. "Joe" Harper, recently promoted to coordinate sales for the Boston, New York and Philadelphia territories.

Mr. Andrews received a B.S. degree in Business Administration from the University of Pittsburgh. Upon graduation he joined the Nordstrom Valve Co. as a salesman, covering Western Pennsylvania and Eastern Ohio. He was later affiliated with the Beaver Pipe Tools, Inc., of Warren, Ohio, as Midwest District Manager. In 1938, Mr. Andrews returned to the Nordstrom Valve Company as a sales engineer with headquarters in Cleveland. He has been Pittsburgh District Sales Manager for seven years prior to his recent promotion.



TRENCH POURED

BELL & SPIGOT JOINTS

Specify McWANE-PACIFIC CENTRIFUGAL PIPE

So, you like to pour your own joints! OK! Trench-poured joints have been a stand-by for close to two centuries. Many thousands of miles of cast iron pipe line with this old stand-by joint have long been in service. Specify McWane-Pacific Super DeLavaud Cast Iron Pipe, in 18-foot lengths. Bells and spigots are uniform, make better trench-poured joints. The pipe is strong, easy to cut and tap. For complete data and prices, write or wire.

McWANE Cast Iron Pipe Company
Birmingham, Ala.
Pipe Sizes 2" thru 12"

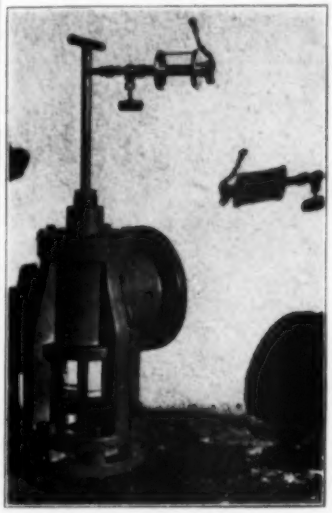
Sales Offices

Birmingham 2, Ala.	P. O. Box 2601
Chicago 1, Ill.	333 North Michigan Ave.
New York 4, N. Y.	80 Broad Street
Kansas City 6, Mo.	1006 Grand Avenue
Dallas 7, Texas	1501 Mercantile Bk. Bldg.

PACIFIC STATES Cast Iron Pipe Co.
Provo, Utah
Pipe Sizes 2" thru 24"

Sales Offices

Provo, Utah	P. O. Box 18
Denver 2, Colo.	1921 Blake Street
Los Angeles 48, Cal.	6399 Wilshire Blvd.
San Francisco 4, Cal.	235 Montgomery St.
Portland 4, Oreg.	501 Portland Trust Bldg.
Salt Lake City	Waterworks Equip't Co.



Cleanable Sight Glass For Sludge Lines

Eliminates Necessity of Sampling Cocks

403

Process Engineers Inc., Los Angeles, Calif., has developed the Process Cleanable Sight Glass that makes it possible for the operator in a sewage plant to observe the characteristics of sludge while being pumped from the sedimentation tanks to the digesters.

The Process Sight Glass was developed to enable the operator to pump the minimum amount of liquid with the sludge into the digester and consequently reduce the amount of digester liquor returned to the sedimentation tank.

(Continued on page 130A)

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

SOUTHWESTERN NORCAM'S *Revolutionary* Sanitary Method cleans Sewer Lines... ...POSITIVELY!

6617 SNIDER PLAZA Telephone LOgan-1361 DALLAS 5, TEXAS

EXPLANATION:

The **NORCAM** Sanitary Cleaning Unit operates between two manholes, cleaning the entire pipe section between, as shown in this diagram.

(1) The **NORCAM** Cleaner (A) is propelled through the sewer main by a head of water in Manhole 1.

(2) The debris cleaned out by the **NORCAM** Cleaner is deposited in Manhole 2.

(3) The pump (P) lifts the debris from Manhole 2 into tank (T) through suction line (C). The 2,000-gallon tank baffles out the debris (R) and returns the clean effluent to the outfall line through line (L).

(4) When the **NORCAM** Cleaner has completed its run through the main, and all debris has been removed, the tank containing the debris is hauled away and dumped.

No mess or refuse is ever placed on the street!

POSITIVELY CLEANED!

Tyler, Texas

At Tyler, an 18" main outfall sewer line in the N.W. section of town was backing up, and running sewerage onto adjacent properties. SOUTHWESTERN NORCAM cleaned 7550 feet of this line, and returned it to its original carrying capacity.

POSITIVELY CLEANED!

Abilene, Texas

SOUTHWESTERN NORCAM was called to Abilene to clean 12,000 feet of sewer mains, consisting almost entirely of 6" pipe. The lines were thoroughly and positively cleaned, and restored to their original carrying capacities, without any damage to the lines. These lines were chronic troublemakers.

POSITIVELY CLEANED!

Anadarko, Oklahoma

In November, 1949, SOUTHWESTERN NORCAM was called to Anadarko to clean several thousand feet of 10" sewer mains. These lines were in an emergency state. By successfully and positively cleaning these troublesome lines, SOUTHWESTERN NORCAM proved what could be done with old lines, and how the city could save money.

Also POSITIVELY CLEANED: Manhattan, Kansas; Memphis, Lubbock and Wichita Falls, Texas; New Orleans, Louisiana and many others.

SOUTHWESTERN NORCAM
PIPE LINE CLEANING CONTRACTORS • Specializing in SEWER MAIN Cleaning

(Continued from page 128A)

The unit is made in 4 and 6 inch sizes and consists of a casting with a special pyrex tube and a cleaning device. It is arranged in the form of a tee so that it can fit into a piping system.

Process Engineers, realizing that the glass would soon become coated with grease and oil and thus become opaque, have provided a cleaning unit that consists of a wiper attached to a hollow shaft through which a solvent, under pressure, can be added. By moving the shaft back and forth and twisting it around, and applying the solvent under pressure, the glass can be easily cleaned. The hand pump that contains a solvent is removable and is attached to the hollow shaft when it is required to clean the glass with the solvent.

Recommended maximum working pressure is 30 psi and the unit can be attached either on the suction or discharge side of the pump.

Permutit Appoints Clyde Poore

Permutit Company, New York, N.Y., has announced the appointment of Clyde R. Poore as Assistant Sales Engineer for its Sales Office located at 831 E. Morehead Street, Charlotte 3, N.C.

In his new capacity, Mr. Poore will work with Norman D. Doane, Sales Engineer, in the sales and service of Permutit Industrial Water Conditioning Equipment.

Born in Middleboro, Kentucky, he received his bachelor's degree in Chemistry from Guilford College, North Carolina.

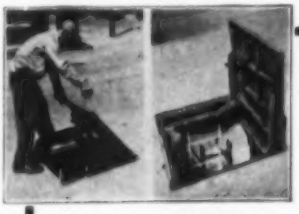
Automatic Program Controller for Chlorinizers

404

Builders-Providence, Inc., Providence, R. I., has announced the availability of the APC—Automatic Program Controller which is a simple and accurate device for controlling the feed of chlorine at predetermined rates for predetermined periods in identical cycles to meet variations in chlorine demand as they may occur.

The Program Controller consists of a simple, cam-operated pressure valve so arranged as to transmit varying pressures to the lower diaphragm pressure chamber of the chlorine control valve in a Chlorinizer. The cams are interchangeable with ease to meet the many variables encountered in chlorine demand and dosage.

Features of the Controller are positive and accurate control, pneumatic or water operation, ease of installation, unlimited variety of programs, simplicity of operation, and long trouble-free service. All of the major elements in the Program Controller are self-contained in a dust-proof case for panel, wall or floor stand mounting.



WACHS SAFETY VAULT COVERS

For Valve, Meter, Transformer and District Governor Vaults

FEATURES

One man can quickly raise cover with ease and without danger.

Cover can not drop into vault or slam to cause injury or damage.

Cover can be opened from the inside of the vault by one man—an added safety feature.

Positive, tamper proof lock that cannot be opened unless key is used.

Open cover stands in upright position indicating that manhole is open.

Unobstructed 30" square opening gives ample room for installation and servicing heavy equipment.

Heavy duty for heavy traffic—cast iron frame and ribbed steel cover both machined for accurate fit to eliminate rattle.

Moisture resistant, heavy cast steel levers and linkage with stainless steel pins in "Oilite" permanent oiled bronze bushings for long trouble-free service.

Complete counterbalance structure protrudes less than 6" from the wall.

WACHS NATIONAL PIPE SAWS

Make Fast And Accurate Cuts on 10" to 48" Cast Iron And Steel Mains

FEATURES

Minimum Pipe Line down time.
Cuts under water in flooded ditches.
No broken pipe, milled out.
Thor-Air Powered, no flames near pipe.
Set-up time about 15 minutes.
Portable—weighs 315 lbs.
Two men can carry and set up unit.
Small excavation—only 16" clearance needed.
One machine cuts all pipe sizes from 10" to 48".
Only two adjustments necessary for size changes.

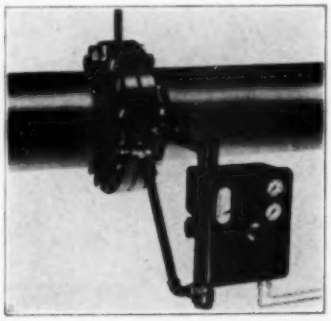
16" clearance between 24" mains.

Cuts 24" pipe in 24 minutes—36" pipe in 36 minutes, etc.

Write today for descriptive folder and engineering data on this new labor saving saw.

THE E. H. WACHS COMPANY

1525 NORTH DAYTON STREET CHICAGO 22, ILLINOIS



New Approach To Orifice Metering

Fischer & Porter V/A Cell Measures By-Pass Flow Rather Than Static Head

405

Fischer & Porter Company, Hatboro, Pa., introduces an entirely new

(Continued on page 132A)

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

LOOKING FOR IMPROVED COAGULATION ?

FREE INFORMATION ON REQUEST

FROM THE

TENNESSEE CORPORATION
Atlanta, Georgia — Lockland, Ohio

ON FERRI-FLOC, THE NEW FERRIC IRON COAGULANT. FREE 35 PAGE BOOK ON WATER AND SEWAGE TREATMENT WITH...

FERRI-FLOC

(Continued from page 130A)

approach to orifice metering with a new product, known as the V/A Cell. Instead of measuring the static-pressure differential across the orifice (as do conventional mercury manometers) the new Fischer & Porter unit meters a continuous by-pass stream around that orifice.

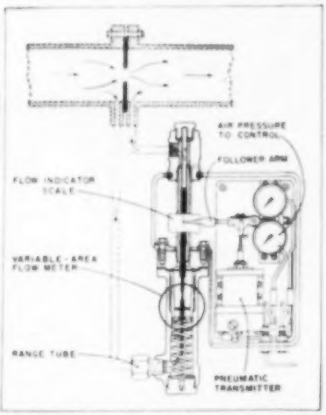
Thus, the metering is kinetic—a constant flow continuously purges the lead lines.

Second, a linear relationship exists between the metered by-pass flow and the main flow past the orifice—avoiding the square-root relationship between manometer action and orifice flow which has so long plagued orifice metering. The linearity and the consequent ten to one rangeability is inherent in the new method.

Third, the new method permits very simple adjustment of the by-pass rate, to give the unit enormous flexibility (usefulness over widely different flow ranges).

A fourth important attribute of the V/A Cell as applied to orifice metering is its adaptability to pneumatic connection to points remote from the orifice run.

In the steam power water treatment and water supply fields these characteristics (kinetic action, linearity, rangeability, flexibility and pneumatic transmission) mean (1) elimination of condensate pots in exposed locations, (2) greater chart (linear scale) accuracy at low flows, and consequently more exact ratio control (as in chlorination or adding water-treatment reagents), (3) enough rangeability to handle variation of steam or water demands with the season or the connected load, and (4) simple central panel control through pneumatic linkage.



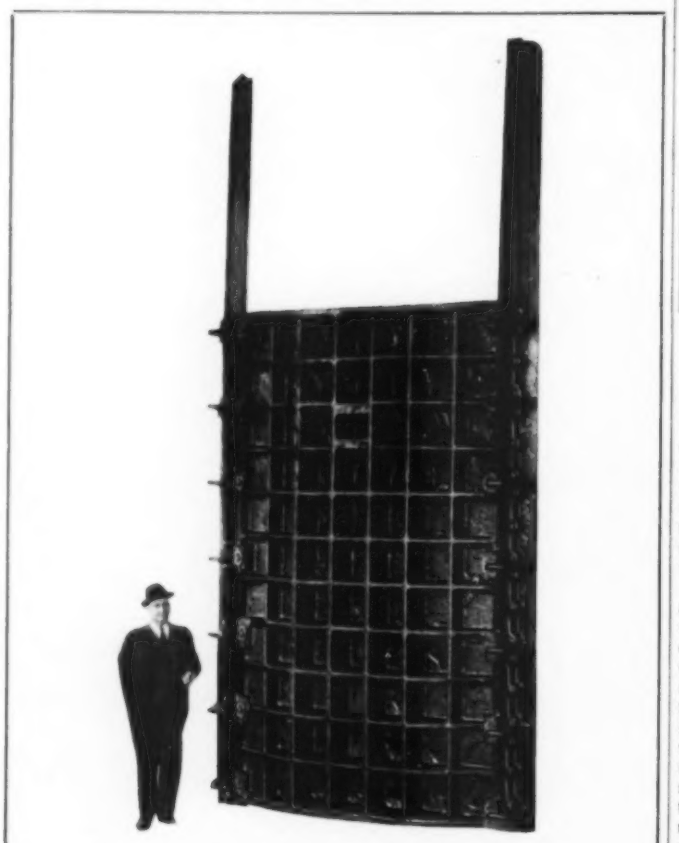
Working Parts of V/A Flow Indicating Cell and Transmitter to Recording Instruments

The principal parts of the V/A Cell are: a variable-area meter whose float position inside a tapered tube changes with flow; a balanced follower arm, magnetically linked to the float; and a pneumatic unit for transmitting flow-rate measurement to remotely-located recorders, indicators, totalizers, ratio controllers or other receiving instruments.

In operation, the cell is connected across the orifice plate in line with usual orifice-metering procedures. It can handle pressure differentials up to 1400 in. of water column. The pressure differential causes a fraction of the flow to pass through the lead lines, range tube, and variable-area flow meter. The carefully-balanced float, riding freely in its tapered tube, is supported at a height determined by the flow. The float, completely free of mechanical linkage and attachments, carries two small alnico magnets which couple it to the yoke of the follower, are without the need for pressure seals, bearings, or bellows. The pneumatic transmitter translates the position of the arm into air pressure and sends this signal, linear with flow, to a receiver instrument.

By changing range tubes at the high-pressure tap, the differential range of the V/A Cell can be varied

(Continued on page 134A)



FILER & STOWELL SLUICE GATES

are built to stand long trouble free service. Amply proportioned for all stresses of shipment, erection and operation. They may be obtained with manual, hydraulic cylinder or motor operating controls.

THE FILER & STOWELL COMPANY
MILWAUKEE 7, WISC.

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

NICHOLS Incinerators

Multiple Hearth Sewage Sludge Dryer-Incinerators

Duohearth Sludge-Refuse Dryer-Incinerators

1. Dependable . . . Designed by engineers with wide experience in incineration. "Down time" reduced to a minimum. Performance records of Nichols incineration equipment show instances of over 300 continuous days of operation before a shut down for minor maintenance.

2. Low Cost . . . Compactness of Nichols design results in low cost plants. Mechanical stoking feature eliminates high labor costs.

3. Simple . . . Nichols basic incinerator design is simple, economical, easy to operate and maintain.

4. Flexible . . . Both the Nichols Multiple Hearth Incinerator and the Duohearth Dryer-Incinerator are engineered to allow diversification of incinerator product. The Multiple Hearth burns sludge to a sterile ash or dries it for use as a fertilizer. The Duohearth meets the requirements of industrial plants and small and medium sized cities by disposing of a variety of waste materials, in addition to sludge.

5. Efficient . . . Incineration cost data compiled over the years prove the efficiency of Nichols Incineration Equipment.

We invite your inquiries.

Nichols Engineering & Research Corporation

70 Pine Street, New York 5, N. Y.

1920 N. Meridian St., Indianapolis 2, Ind. 40 S. Los Robles Ave., Pasadena 1, Calif.

1477 Sherbrooke St. W., Montreal 25, Canada

THE SILENT WATCHMAN

DIXIE TANK AND BRIDGE CO.

3523 LAMAR AVE. P. O. BOX 14

MEMPHIS 1, TENNESSEE

Complete Service for Elevated Water Tanks—
Nation Wide Service—33 Years Experience

KEEP THE SAFETY FACTOR IN YOUR TANK THE DIXIE WAY

By welding seams, pits and rivets which gives a riveted tank 15% more Safety Factor than it had when built. No rivets removed, water supply maintained while work is in progress. On completely reconditioned jobs, the painting is guaranteed for three years, repairs guaranteed for ten years, provided the tank is painted every three years by Dixie Tank and Bridge Company, making all adjustments, if any, without additional cost.

Write Us for Free Copy of Publication

SOUND PRINCIPLES OF WATER TANK MAINTENANCE and TANK TALK, by W. A. RILEY

Dixie's Nation Wide Service Satisfies

COPYRIGHT 1951

THE LARGEST ORGANIZATION OF ITS KIND GIVING SAFE MAINTENANCE AT LOW COST

(Continued from page 132A)

from 50-in. to 1400-in. in standard increments with a usable flow ratio of ten to one at the 200-in. differential. The unit has three visual indicators: A parallex-free flow indicator scale, an air-supply gage, an output-pressure gage. The pneumatic transmitter consumes 0.15 cfm of air and transmits 3 to 15 psig.

Float chamber and float are constructed of type 316 stainless steel making the cell corrosion-resistant and giving it a maximum operating temperature of 650°F. Continuous purge of line material diminishes the tendency of gases and solids to build up in lead lines and thus eliminates the need for exterior purges. Design characteristics of the V/A Cell give it unlimited overrange up to the full working pressure limit.

To satisfy wide metering requirements, the V/A Cell is manufactured in two models: one with working pressure rating of 1040 psi at 350°F or 1200 psi at 100°F; the other rated at 2600 psi at 350°F or 3000 psi at 100°F. All floats, float chambers and range tubes are inspected for performances and dimension.

The 9 x 11 x 7 inch, light-gray, hammer tone, aluminum cell-case is moisture and fume proof. It can be mounted at the orifice flange or up to 30 feet from the orifice flange.

The V/A Cell is also available with the Fischer & Porter Rotatronic electric transmitter and/or electric alarm switch.

SMITH BLAIR

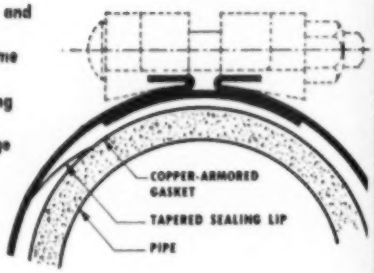
Full Circle CLAMP COUPLINGS

Widths: 5" to 30"
Sizes: 2" to 12"

★ For PERMANENTLY repairing broken or cracked pipe

By utilizing the flexibility, durability and strength of copper or stainless steel, the Smith-Blair Full Circle Clamp Coupling has proved itself to be a revolutionary repair unit. It is fast becoming the standard method of repair for the water works throughout the United States and Canada. It is a permanent repair unit for any type of pipe.

- Lowers Initial Cost
- Minimizes shut downs and shut down time
- Reduces installation time required
- Requires less excavating for installation
- Gives higher percentage of complete shut-offs on the first try — under pressure.



MANUFACTURERS OF: REPAIR CLAMPS; FULL CIRCLE CLAMP COUPLINGS; WATERLOCK RINGS; FLEXIBLE COUPLINGS; SERVICE CLAMPS; OTHER SPECIALTIES

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SEND FOR CATALOGUE DESCRIBING SMITH-BLAIR PRODUCTS
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POSITION
ADDRESS
A

Badger Meter Loses President

Charles W. Wright, for twenty-three years president of Badger Meter Manufacturing Co. of Milwaukee, Wis., passed away on February 14th, the victim of a heart attack. He was 60 years old.

Mr. Wright, who had been connected with Badger Meter Co. since 1924, became president in 1929, and chairman of the board subsequently. He was a native of Alexandria, Va., and attended Georgetown University. He served in the U.S. Navy during World War I. Prior to his connection with Badger Meter Co., for ten years he was with the A. O. Smith Corp., of Milwaukee.

Mr. Wright was a director of the Lindemann and Haverson Co., a member of the Milwaukee Club, Milwaukee Country Club, Univ. Club, and the Phi Alpha Delta Fraternity.

From 1942 until 1945 he operated a basement enterprise in his home which was managed by Mrs. Wright whose friends were the workers. The Wright's basement shop produced small machined parts for aerial and depth bombs and airplanes, turning out 92,000 pieces weekly under contract with the armed forces procurement departments.

Besides Mrs. Wright, daughter of the late A. O. Smith, Mr. Wright leaves a daughter and three sons, James O., William C., and David L. It is probable that one of his sons, James O. Wright, will succeed his father as Badger's new president.

Throttling Control Valves

406

Conoflow Corporation, Philadelphia, Pa., and Paul Valve Corp., have collaborated in the development of a complete line of throttling control

(Continued on page 136A)

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

HELLIGE TURBIDIMETER

A TURBIDIMETER ACCURATE ENOUGH FOR LABORATORY USE

FOR TURBIDITY MEASUREMENTS, SULFATE DETERMINATIONS, AND SPECIAL APPLICATIONS

Modern in design and operating principle, the Hellige Turbidimeter does not require standard suspensions or long cumbersome tubes. Accurate readings can be made rapidly by those without technical training.

Precise determinations are performed in the ranges of zero to 150 p.p.m. SiO_2 and zero to 100 p.p.m. SO_4. Higher values are determined by diluting the specimen.

Send for Catalog No. 8000-A

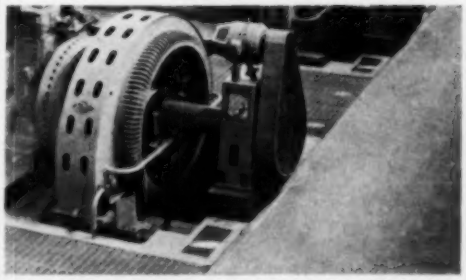
HELLIGE *Inc.*

4110 NORTHERN BLVD., LONG ISLAND CITY 1, N. Y.

for FLOORING WALKWAYS STAIRWAYS DRAIN GRATES in WATER and SEWAGE WORKS

Specify IRVING GRATING and TREADS

and get CLEAN DRY SAFE SMOOTH TRACTIVE DURABLE VENTILATING ECONOMICAL SURFACES



IRVING ALUMINUM GRATING-FLOORING BETWEEN MACHINES IN POWER AND BLOWER BUILDING OF SEWERAGE DISPOSAL PLANT

IRVING SUBWAY GRATING CO., INC.

ESTABLISHED 1902

5089 27 ST., LONG ISLAND CITY 1, N. Y.

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REPRESENTATIVES IN PRINCIPAL CITIES LISTED IN PHONE BOOK UNDER IRVING SUBWAY GRATING. LICENSEES IN CANADA AND MEXICO.

for dependable

AERATION

in your activated SLUDGE PLANT

specify HOFFMAN

CENTRIFUGAL BLOWERS

DEPENDABLE—no gears, valves or similar wearing parts. Operate 24 hours a day, for years without adjustment or replacement of parts.

ECONOMICAL—Power input varies with volume of air required. Retain original efficiency indefinitely—deliver full rated capacity continually.

ALL CAPACITIES UP TO 10,000 C. F. M. AND VARIOUS AIR PRESSURES UP TO 8 LBS.

Write for Bulletin A-650

U.S. HOFFMAN MACHINERY CORPORATION

211 FOURTH AVENUE, NEW YORK 3, N. Y.

CANADIAN PLANT: CANADIAN HOFFMAN MACHINERY CO. LTD., NEWMARKET, ONT.

STOP

JOINT LEAKAGE

Use

CARSON CLAMPS

With Pearlitic C.I. Bolts for Cast Iron Pipe and Fittings.

Write for Prices

H. Y. Carson Company

1221 Pinson St. Birmingham, Ala.

(Continued from page 134A)

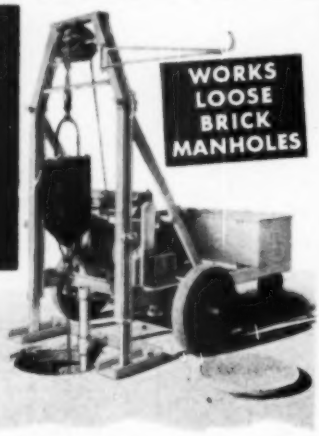
valves utilizing Conoflow Pneumatic Cylinder Operators and Paul Venturi Ball Valves.

The Paul Valve features a precision ground ball, actuated by the Paul venturi ball principle. With the combination of the Conoflow operator and Paul valve it is possible, according to the company, to greatly simplify many difficult control problems involving corrosive fluids, abrasive materials, high temperature and high pressure applications and other difficult services.

Since the Cono-cylinder operator utilizes a positioning mechanism as a component part, the assembly can be used in conjunction with standard pneumatic control instruments for automatic control, or with manual loading stations for remote manual positioning.

The streamlined venturi passages and smooth surfaced ball provides a non-turbulent flow stream eliminating cavitation, as well as increasing capacity and improving controlability. Inherently a single seated valve, the Paul principle reduces unbalanced forces to unusually low values so that the advantage of tight shut-off may be obtained without sacrificing control sensitivity.

FLEXIBLE
"Surface-Hung"
MANHOLE
ROLLER

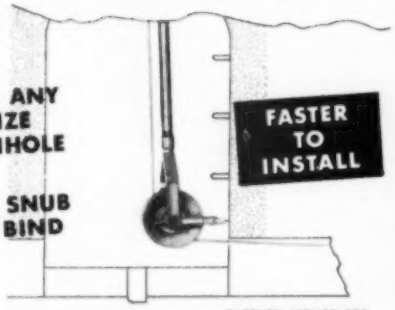


It's New!
Revolutionary!

- Operates at any angle of circle without moving machine. Adjust platform only.
- Installs in a fraction of the time of ordinary jacks. No holes to chisel in bricks.
- Hangs in manholes too narrow for present jacks.
- No rebuilding of manholes necessary. Operates in "loose brick" manholes.
- Less snub on roller eliminates cable bind. Bucket passes easier.

FITS ANY SIZE MANHOLE

LESS SNUB NO BIND



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351 West Jefferson Blvd. — Dallas, Texas

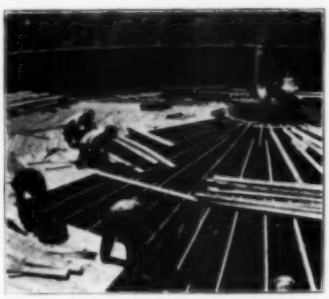
AMERICA'S LARGEST MANUFACTURER
OF PIPE CLEANING TOOLS AND EQUIPMENT

U. S. Motors to Build $3,500,000 Plant

U. S. Electrical Motors, Inc., Los Angeles, Calif., has announced that it will begin construction of a $3,500,000 plant on the Santa Ana freeway, between Anaheim and Buena Park, California.

The administration building will occupy 50,000 sq. ft. and will be of modern design. Construction is to be of ornamental brick and reinforced concrete. The frontage will be landscaped with spacious lawn and tropical flowers.

Manufacturing buildings of the new plant will occupy a covered area of 250,000 sq. ft., with provision for eventually increasing this area to 700,000 sq. ft.



Wolmanized Wood for Sewage Plants

407

American Lumber & Treating Co., Chicago, Ill., has announced that Wolmanized lumber is now being used in the construction of roof decks for digester tanks.

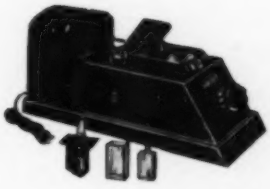
Wolmanized lumber is lumber that has been impregnated under high pressure in heavy retorts with a so-

(Continued on page 138A)

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

KLETT SUMMERSON
ELECTRIC PHOTOMETER

Adaptable for Use in Water Analysis

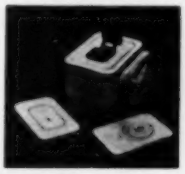


Can be used for any determination in which color turbidity can be developed in proportion to substance to be determined.

KLETT MANUFACTURING CO.
179 EAST 87th STREET • NEW YORK 28, N.Y.

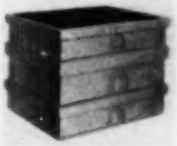
ART CONCRETE
VALVE AND METER BOXES

Whatever your valve and meter box requirements are Art Concrete Works offers a style and size to meet your needs. Shown here are but three of the many styles of boxes available. Experience gained during more than forty years of leadership in the field, our technical knowledge and engineering service . . . are available to you upon request.



NO. 36 SERIES . . . This style of meter box is available in a wide range of sizes to accommodate ¾" to 3" meters and shut-off. Reinforced concrete or cast iron covers available. Extension sections may be had for extra depth.

SECTIONAL METER BOXES . . . Each section of these reinforced concrete boxes securely rests in the cover seat of the tier below. Available in standard widths and lengths up to 60" I.D. and may be assembled on the job to any required depths in units of 12" and 18".



GATE VALVE BOXES . . . These extensible traffic valve boxes are designed for use in locations that are subject to constant vehicle traffic. They may be used with any metallic or non metallic pipe as a sleeve, or non-metallic pipe as a sleeve.

Write for catalog showing the complete line of Art Concrete Meter Boxes and Valve Boxes.

Nine Factories To Serve You

ART CONCRETE WORKS
PASADENA, CALIF.

GEOPHONE*

Does Away With Costly, Old-Fashioned Methods of Locating Leaks!

• MONEY-SAVING
• ACCURATE
• FAST

★ The Globe Geophone scientifically and accurately locates water and steam leaks. There's no costly, time-consuming excavation when a Geophone is used. A compact and sensitive instrument operating on the principles of the seismograph and stethoscope, the Geophone picks up and detects, even when 50 to 75 ft. away, the vibrations of the pipe break, and locates it accurately within a few minutes.

The Geophone is indispensable for Water Departments and Industrial Plants. Used also with spectacular results in mining, oil and termite fields.

Complete Geophone outfit consists of connecting tubes, two Geophone discs, headpiece and heavy leather-covered carrying case with shoulder strap. **$85**

Pipe Phones $3.70
(Aquaphone)

Globe Phone Mfg. Corp. READING, MASS. DEPT. F
Manufacturers of Geophone Since 1918
Registered in United States Patent Office

BEST DEFENSE AGAINST CORROSION

Start with
TYGORUST
"the no-prep vinyl primer"

- minimizes surface preparation
- brushes easily—sprays beautifully
- dries hard in 5-15 minutes
- covers up to 500-600 sq. ft./gal.
- goes under any type finish
- adheres to wet or dry rusted steel, to wood, to concrete, or to previously painted surfaces.

Finish with
TYGON "Series TP" PAINT
"the vinyl finish of maximum protection"

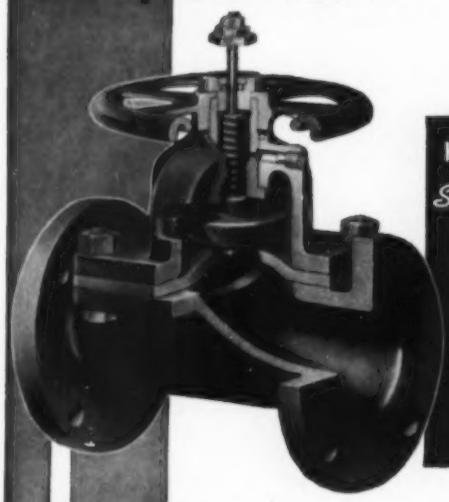
- easily applied by brush or spray
- fast drying and non-oxidizing
- fully flexible and chip-resistant
- non-flammable when dry
- easy to clean and long lasting
- resists fumes and spillage of acid, alkalies, oils, greases and water.

Write for full details—ask for Bulletin 720!

360 C

U. S. STONEWARE CO.
AKRON 9, OHIO

Here is the valve that revolutionized flow control of Sulphuric Acid . . .



HILLS-McCANNA
Saunders Patent
DIAPHRAGM
VALVE
with L-1
PLASTIC
DIAPHRAGM

Sulphuric acid up to 66° Bé can now be valved without leakage, dripping or sticking . . . with Hills-McCanna Diaphragm Valves equipped with the new L-1 plastic diaphragms. This new development combines the tried and proved Saunders Patent pinch clamp principle with a diaphragm of a special type of plastic that is particularly resistant to concentrated sulphuric acid.

Hills-McCanna Diaphragm Valves with L-1 diaphragms are suitable for temperatures up to 125° F. and pressures up to 100 psi. Sizes from ½" thru 4" are available, handwheel operated, quick opening (lever operated) and sliding stem models. Choice of nearly 50 body materials or linings including cast iron, cast steel, Durimet or glass lined.

Literature is available describing Hills-McCanna Valves with data on their use for acid and other services. Write for your copy outlining the nature of your application. HILLS-McCANNA COMPANY, 2357 W. Nelson St., Chicago 18, Ill.

The valve illustrated in cut-a-way above is the Hills-McCanna Model 600 semi-sealed bonnet acid valve with L-1 plastic diaphragm and tell-tale travel stop indicator. Valves of this type can be furnished where particularly rigid safety precautions are taken.

HILLS-McCANNA CO.

saunders patent

diaphragm valves

Also manufacturers of — Proportioning Pumps
Force-Feed Lubricators • Magnesium Alloy Castings

(*Continued from page* 136A)

lution of Wolman preservative salts. First the lumber is placed in a steel cylinder and the door to the cylinder is bolted shut. A vacuum of 24 inches mercury is pulled in the cylinder to dry the surface of the wood and increase receptivity to treatment. As the vacuum is held, a solution of the Wolman salts heated to 140°F. is admitted to the cylinder. When the cylinder is full of solution the vacuum is broken and a pressure of 150 p.s.i. is applied. The pressure is then held while the solution is forced deeply into the wood. This treatment is said to assure protection against rot and decay.

Purdie Receives 40 Year Service Award

Builders Iron Foundry, Providence, R. I., has announced that David J. Purdie, Sales Engineer and District Manager of the New York Branch Office for Builders-Providence, Inc., Omega Machine Co. and Proportioneers, Inc., completed his 40th consecutive year of service last year. Mr. Purdie received recognition and honor for this service at the annual Award Dinner in Providence. Also honored for 40 years service was Henry Zoglio, Assistant Superintendent of the foundry.

G. E. Offers New Line of Fractional Horsepower Motors

408

General Electric Company, Schenectady, N.Y., has announced a new line of fractional horsepower motors embodying an entirely new concept of motor design and manufacture.

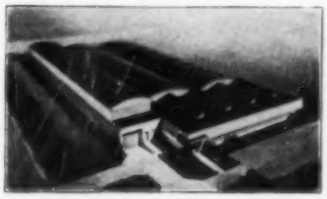
Designated as "Form G," the new motors are the result of nearly a decade of developmental engineering and research, and incorporate many radically different and advanced design features.

According to G-E engineers who worked on the project, the Form G motor weighs as much as 51 per cent less per horsepower than the models it replaces and is considerably smaller in size. At the same time, its versatility of application has been broad-

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

ened and its appearance modernized.

The motors are available in open drip-proof and totally enclosed fan-cooled models in Types K (polyphase), KC (capacitor start), KH (split phase), and KCP (permanent split capacitor). Built to conform fully with NEMA specifications, the motors will be offered in a complete range of standard horsepowers, speeds, voltages, and frequencies.



Yeomans Grows into New Factory

Yeomans Brothers Company, Chicago, Ill., has started construction of a new and modern one story factory, with 92,000 square feet of floor space, in Melrose Park, Ill.

It is anticipated that the new factory will be ready for occupancy in the fall of 1952.

New Product Stops Direct Leaks Below Grade in 30 Seconds Without Removing Hydrostatic Pressure

409

Dasco Company, Inc., Baltimore, Md., has developed a new product "Dasquik" that is said to stop direct leaks with up to 40 psi in 30 seconds without removing the hydrostatic pressure.

According to the company, this product was developed after many years of laboratory and field testing and has now been accepted and is in use by the U. S. Army, Air Force, Navy, Water Departments and Public Utilities.

"Dasquik" is an extremely fast setting purple liquid that has been de-

"Quit worrying about lost production and do something!"

SARAN LINED steel pipe

Right now is the time to act! Take steps toward preventing costly production delays in the future. Specify corrosion-resistant saran lined steel pipe! You'll find, as have many of the country's leading manufacturers, that this remarkable pipe means dependable long term operation at a minimum maintenance cost. Saran's unusual resistance to most chemicals and solvents plays an important part in the reduction of shutdowns and lost production. Another noteworthy advantage is its ease of field fabrication involving NO costly delays with special tools or handling.

These advantages are all important to you, so "quit worrying and do something." For detailed information mail this coupon to The Saran Lined Pipe Co.

Saran Lined Steel pipe is manufactured by The Dow Chemical Company.

Distributed by

Saran Lined Pipe Company

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Offices in: New York • Boston • Pittsburgh • Tulsa
Philadelphia • Chicago • Portland • Indianapolis
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Please send me a copy of your catalog on Saran Lined Pipe, Valves and Fittings.

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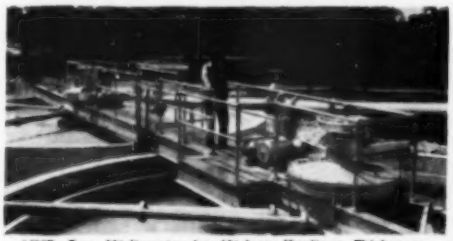
WATER
creates
a
problem
HARDINGE
CLARIFIERS
or
THICKENERS
can
solve it

Hardinge has installed waste water treating or reclaiming equipment for the following industrial operations:

COAL
PAPER
OIL
GLASS
LIME
STONE
SAND
FLUE DUST
CARBON BLACK
MEAT PACKING
RUBBER
DOMESTIC SEWAGE

Write for Bulletin 35-C-15

COAL—120'-diameter Hardinge Clarifier for removing 60 tons per hour of solids from coal breaker waste water.



LIME—Two 32'-diameter by 15'-deep Hardinge Thickeners reclaiming calcium carbonate for lime production from clarifier underflow in a water-treating plant.

FLUE DUST—A 110'-diameter, center-pier Hardinge Clarifier recovering 50 tons per day of usable solids from blast furnace flue waste water in a steel plant.

PAPER—30'-diameter Hardinge Thickener recovering 2 to 2½ lbs. of fiber and filler per 1,000 gallons of paper plant waste water.

HARDINGE
COMPANY, INCORPORATED
YORK, PENNSYLVANIA—240 Arch St. Main Office and Works
NEW YORK 17 • SAN FRANCISCO 11 • CHICAGO 6 • HIBBING, MINN. • TORONTO 1
122 E. 42nd St. 24 California St. 205 W. Wacker Dr. 2016 First Ave. 200 Bay St.

veloped for extreme pressure leaks. It has an initial setting time of 15 seconds and a final setting time of 30 seconds when mixed with fresh plain Portland cement. It is stated that it will stop leaks against pressure without removing the pressure and can be applied by unskilled labor without fear of recurrence.

According to the manufacturer, "Dasquik" does not contain Calcium Chloride, Ammonium Sterates, Metallics, Silicones, Waterglas, or other water-proofing agents of this type.

Dravo Appoints Beidler

Dravo Corporation, Pittsburgh, Pa., at a meeting of the corporation's Board of Directors, appointed John K. Beidler General Manager of the Machinery Division.

He was also elected a director and a Vice President of Dravo-Doyle Company, a subsidiary. In taking over general managership of the Machinery Division, Mr. Beidler fills a vacancy created by the death earlier this year of Walter P. Berg.

Mr. Beidler joined Dravo Corporation in 1935, a year after his graduation from Lehigh University. His first position was sales engineer for Dravo industrial heating equipment in the Chicago area. Later he became Purchasing Agent of the Machinery Division and in January, 1950 was named Assistant General Manager of that division.

Armstrong Joins Builders on West Coast

Builders-Providence, Inc., and Omega Machine Co., Providence, R. I., have announced the appointment of Luther W. Armstrong as Service engineer for the states of Oregon and Washington, and the

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

provinces of British Columbia and Alberta, Canada.

Mr. Armstrong holds a B. S. in Chemical Engineering and prior to joining Builders-Providence, was a design engineer specializing in sewage treatment plants with Cary-Cramer & Associates, Seattle. He was at one time with J. E. Sirrine & Co., Greenville, S. C., supervising pilot plant operations; designing sewage treatment plants; supervising water treatment installations, and working on paper mill and dye plant design.

In 1948 Mr. Armstrong contracted with the City of Brisbane, Australia, for design work on resewering Brisbane and advanced planning of an activated sludge installation.

Variable Speed Units

410

Sterling Electric Motors, Inc., Los Angeles, Calif., announces the addition of Type KFEA variable speed units with single reduction gears in ratings of 20 and 25 horsepower.

These units are manufactured in speeds of 728 r.p.m. and lower with infinite speed adjustment within the ranges of 2:1, 3:1 or 4:1.

Features of the drive are: positive adjustment of pulleys, accurate maintenance of speeds under varying loads, belt tension in proportion to load, positive oil seals, single train helical gears, Herringbone Rotor, and direct-through ventilation. All ratings are available with drip-proof or splash-proof construction.

Josam Completes New Office Building

Josam Manufacturing Company, Michigan City, Ind., has announced

BETTER BE SAFE THAN SORRY WHEN YOU'RE MOVING GAS OR AIR

- ☐ Choice of Rotary or Centrifugal
- ☐ Capacity matched to the job
- ☐ Easy accessibility
- ☐ Ruggedness
- ☐ Ease of installation
- ☐ Ability to handle overloads
- ☐ Long-time durability
- ☐ Freedom from breakdowns
- ☐ Low maintenance costs
- ☐ Engineering assistance
- ☐ Proved reputation of maker
- ☐ Customer satisfaction

Battery of four 3-Stage Centrifugal Blowers in metropolitan sewage treatment plant. Capacity of each, 15,000 cfm.

You can't afford to take chances when the successful operation of a sewage treatment plant depends upon maintained performance of blowers or gas pumps. So, we suggest that you check carefully the above factors before you make your final decision.

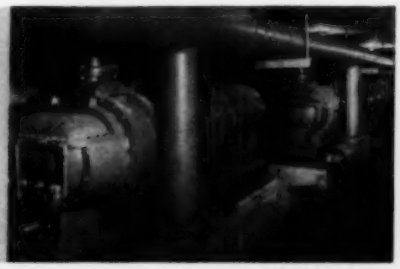
If you are faced with a choice between Centrifugals or Rotary Positives, remember that only Roots-Connersville makes both types. From our exclusive *dual-ability line*, with capacities from 100 cfm to 100,000 cfm or higher, at moderate pressures, most buyers can find a unit closely matched to their specific needs.

We'd like to remind you, too, that for almost a century we've built only blowers and related equipment. Our products have a long, happy record for outstanding, reliable, economical performance in large and small sewage treatment plants and waterworks. Our vast reservoir of experience is at your service, to meet any problem of handling gas or air.

ROOTS-CONNERSVILLE BLOWER CORPORATION
524 Mount Avenue, Connersville, Indiana

ROTARY

In the plant illustrated above, three R-C Gas Pumps are used for boosting pressure from gas storage to engines.



Reg. U. S. Pat. Off.

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ONE OF THE DRESSER INDUSTRIES

SINCE 1885

GRUENDLER

the choice again in

1951

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GRUENDLER
SEWAGE—GARBAGE SHREDDERS

Disintegrate the waste for continuous flow!

Bulletin S. G. 10 mailed on request

GRUENDLER
Crusher & Pulverizer Co.

Plant and Executive Office

2918 North Market
St. Louis 6, Mo.

the completion of a new office building in Michigan City, as well as additional plant facilities.

This step in Josam's new expansion program, as explained by Mr. L. N. Newman, Executive Vice President, is a continuation of the growth experienced by Josam in Michigan City since the plant was first located there in 1917. The new expansion represents the fifth large step in the program to the point where today the new factory and foundry, covers almost 4 acres of ground.

Josam's executive and sales offices, were formerly located in Cleveland, Ohio.

Compression Pipe Coupling

411

Morris Coupling & Clamp Co., Ellwood, Pa., has announced a new style compression pipe coupling which practically eliminates turbulence at the joint. According to the company, more than a year's testing and service in the field has proved the coupling's ability to materially reduce electrolytic corrosion and turbulence at the pipe joint.

The coupling is made up of three parts: 1) a gasket made of the material best suited to give protection for the specific job application, 2) steel

M-SCOPE Pipe Finder

LIGHTWEIGHT MODEL

One Man Operation

HIGHLY EFFICIENT

IMMEDIATE SHIPMENT

Catalog No. 25G On Request

JOSEPH G. POLLARD CO., INC.

Pipe Line Equipment

New Hyde Park New York

MACHINE *Blending*.. BALANCED *Formula*.. gives you UNIFORMITY of

BOND-O Self Caulking Compound is an accurately formulated, precisely controlled *homogenized* compound for joining cast-iron bell and spigot water pipe.

Blended by a unique machine mixing process, BOND-O provides for easily poured, trouble-free joints of *absolute uniformity* in tightness, bonding characteristics and strength.

Hundreds of thousands of perfect seals, in countless miles of water mains laid in over 600 American municipal systems and 11 foreign countries, testify to the reliable performance and economy of BOND-O joints.

No failure of a BOND-O joint has ever been reported!

BOND-O

the perfect jointing compound

NORTHROP & COMPANY, INC.
SPRING VALLEY NEW YORK

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

inner sleeve with precision die-cut teeth placed eccentric to the gasket teeth to form a complete seal when the outer shell is tightened, and 3) steel outer shell made of zinc coated steel or corrosion resistant metals when required, with zinc coated washers, bolts and nuts.

Cable for Pneumatic and Hydraulic Control Circuits

412

Bailey Meter Co., Cleveland, Ohio, has developed a new flexible, protected multi-tube transmission line for pneumatic and hydraulic control circuits.

Called Armortube Cable, it is made up of ¼ inch O. D. aluminum or copper tubing gathered in a slow continuous spiral similar to the construction of rope. A tube bundle is first wrapped in water-repellent insulating tape; then encased in heavy rust-resistant, galvanized steel strip like that used for BX electrical cable.

Available in bundles of 4, 8, and 12 tubes, Armortube Cable is capable of transmitting hydraulic control pressures as high as 3000 psig. and all ranges of pneumatic control pressures. Connections and take-offs maye be made in standard electrical junction boxes. Standard pipe or conduit clips may be used to fasten the cable to walls or ceilings.

Chicago Bridge & Iron Appoints Mitchell

Chicago Bridge & Iron Co., Chicago, Ill., has announced the appointment of Marvin G. Mitchell as Manager of the company's Atlanta, Ga., Sales office, located at 57 Forsythe St. Mr. Mitchell will be assisted by J. W. Hoerner and B. S. Jenkins, Contracting Engineers.

Thomas A. McEinstein admits his METER SHORT-FORM is a Flop!

No matter how cute a formula an inventive genius may develop to correct meter readings to what they would have been if the meter had been set in the position specified, he eventually comes to the conclusion that it doesn't pay to install a water meter sideways in a vertical water line. He should have used a Ford Copperhorn in the first place and kept his meter on the level . . . and it doesn't take a cost accountant or a time-study specialist to prove it. Write today for full information.

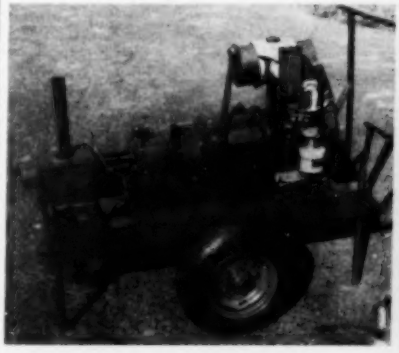
It's a cinch with a Copperhorn!

THE FORD METER BOX COMPANY, INC.

FOR BETTER WATER SERVICES

FORD

Wabash, Indiana

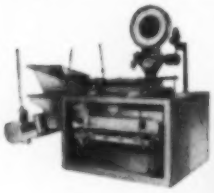


GATE OPERATORS — PORTABLE — FOR STANDS & UNDERGROUND GATES—MOTOR TRUCK MOUNTED

PAYNE DEAN & CO.
CLINTON, CONN.

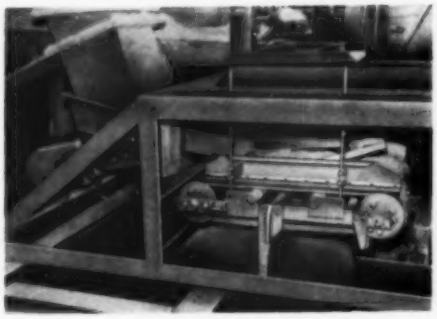
If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

SYNTRON



"Weigh-Flow"

Gravimetric Feeders



provide
Accurate Control
in the
Continuous Feeding
of **Bulk Materials**
at a **Constant Weight**

Smooth out those "Surges" in your Production Chart

If you require accurate ingredient control, and your process is a continuous one—Syntron Gravimetric Feeders will provide that control, automatically.

The combination of a scale-mounted, constant-speed belt—with the Feeder's operation regulated by the overweight and underweight movement of the scale—maintains the desired weigh flow of material per unit of time.

Small models for handling up to hundreds of tons per hour.

Write Today for FREE Illustrated Folder

SYNTRON COMPANY
650 Lexington Avenue Homer City, Penna.

This outstanding result is produced with N-Sol (Activated Silica) as coagulating aid. Paper mill wastes are clarified so they can be re-used or discharged directly into streams. In addition, recovery of fiber, filler and other chemicals saves money.

N-Sol (Activated Silica) is economical to use . . . prepared in the mill from N® Silicate of Soda and a reactant such as chlorine, alum, ammonium sulfate, sodium bicarbonate. Samples of "N" and directions for jar tests for raw water and wastes on request.

PHILADELPHIA QUARTZ COMPANY
Manufacturers of Soluble Silicates
1106 Public Ledger Bldg., Philadelphia 6, Pa.

Mr. Mitchell started with Chicago Bridge and Iron Co. on June 19th, 1939. He worked in their drafting rooms, shop and erection department and was transferred to the Sales department on Sept. 10th, 1944. He since worked in Birmingham, Atlanta and Tulsa offices.

A native of Georgia, Mr. Mitchell graduated from Georgia Institute of Technology with a Bachelor of Science degree in Civil Engineering in 1939.

Silicone-Base Waterproofing Compound

413

Speco, Inc., Cleveland, Ohio, has announced "Dam-Tite," a new silicone-base water repellent for exterior masonry surfaces.

According to the manufacturer, "Dam-Tite" is a completely colorless liquid which penetrates masonry surfaces up to ⅜ of an inch, waterproofing the pore walls without plugging them or preventing air passage. It can be sprayed or brushed on brick, concrete, stucco, stone, unglazed tile or asbestos shingle surfaces.

Because of its water repellency, "Dam-Tite" keeps damaging moisture from reaching interior walls and at the same time prevents exterior chipping, cracking and frost damage. It is also reputed to prevent oxidation with its resulting unsightly efflorescence.

Chicago Pump Moves Offices

The Chicago Pump Company, Chicago, Ill., has announced the removal of their Executive and General Offices to 622 Diversey Parkway, Chicago 14, Illinois.

The company also announced that there would be no change in the ad-

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dress of the factory, service department, or plant No. 2. The service department telephone number has been changed to BElmont 5-7660.

Literature & Catalogs

Pneumatic Ejectors

414

Yeomans Brothers Company, Chicago, Ill., has just published a new 12-page catalog describing all types of **Shone Pneumatic Ejectors.**

The catalog presents complete information on both mechanically and electrically controlled ejectors for pumping, sewage, drainage and solids-carrying liquids. Also included is a complete list of installations and an Engineering Data Manual.

Water Supplies Catalog

415

Layne & Bowler, Inc., Memphis, Tenn., has recently compiled a series of catalogs and bulletins on **Water Supply.** The general catalog covers the equipment manufactured by Layne and Bowler.

These amply illustrated catalogs cover: Layne Well Water Systems; Gravel Wall Wells; Tubular and Rock Wells; Special Drilling; Shutter Screens; Vertical Turbine Pumps; Water Treatment and Water Conditioning; Engineering and Useful Tables; Cemented Wells; and Short Coupled Service Pumps.

Proper Valve Lubrication

416

Minneapolis-Honeywell Regulator Company, Brown Instruments Division, Philadelphia, Pa., has just published a bulletin on **Proper Valve Lubrication, Prerequisite to Good Control.**

The bulletin discusses the importance of proper valve lubrication in keeping valves operating at peak efficiency. Also covered are the function, proper selection, methods of application and the various types of lubricants in general use.

A table on the last page shows the various lubricant numbers, temperature ranges, colors, solvents, and recommended services.

Filter Gauges

417

Builders-Providence, Inc., Providence, R.I., has announced a new bulletin on **Filter Gauges, Mechanically Operated.** This bulletin de-

Write Today for 66 Page Catalog

W. S. DARLEY & CO., Chicago 13

SERVICING
FEDERAL
STATE
COUNTY
MUNICIPAL
AND
INDUSTRIAL WATER TOWERS

SPEELMON ELEVATED TANK—SERVICE

COMPLETE PAINTING AND REPAIR SERVICE

822 N. Court St. Rockford, Ill.

Warren FOUNDRY & PIPE CORP.

55 LIBERTY STREET, NEW YORK 5, N. Y.

Bell & Spigot Pipe • Flange Pipe • Mechanical Joint Pipe

Flexible Joint Pipe • Short Body Bell & Spigot Specials

WARREN PIPE CO. OF MASS. INC. 75 FEDERAL ST. BOSTON, MASS.

95 Years of Continuous Service

Every city, town, village where sewer pipe, water or gas lines are laid has buried thousands of dollars in the ground.

It's buried treasure . . . easy to locate but of value *only* if it has the proper crushing, beam shock and bursting strength properties.

Cast Iron Pipe serves for centuries. Figures prove it . . . so does the pipe itself!

Available in sizes from 2 inches to 84 inches.

Send for prices and specifications

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

FOR SALE

Unused River Water Treatment Equipment

1—Model 35G-100 gear drive "Lightnin" Tripod Mounted Mixer with motor, made by Mixing Equipment Company.

1—Dorrco Hydrotreator Type W with appurtenances and miscellaneous service, made by the Dorr Company.

1—Manual Control Solution Feed Master Vacuum Chlorinator Type MMSV, complete with all standard accessories, made by Wallace and Tiernan Company, Incorporated.

Fairbanks-Morse Figure 6360 Vertical Mixed Flow Propeller Type Pumps, Two-Stage, with Motors:

2—No. 14
2—No. 8
1—No. 12

None of these items have ever been used. Other details furnished upon application.

Write: Water & Sewage Works
22 W. Maple St.
Chicago 10, Illinois
Box 1083

scribes the various models of Filter Gauges manufactured by the company.

In addition to the description of these instruments, this bulletin also briefly relates the principle of operation used in these gauges. The Diaphragm Pendulum Unit, which is usually an integral part necessary in the operation of most filter gauges, is discussed, pointing out its outstanding features. Many of these gauges are used for recording water level in which case the Diaphragm Pendulum Unit is not needed. A few special gauges are also considered in this bulletin.

Pipe Line Strainers

418

J. A. Zurn Mfg. Co., Erie, Pa., has just published a new **Pipe Line Strainer Data Manual** which describes and illustrates several types of pipe line strainers for all purposes ranging in sizes from ½ to 36 inches.

Summarizing important developments resulting from Zurn's continuous engineering research in fluid handling equipment, this illustrated manual carries information on the factors to consider in selecting type and size of strainer for a specific application, and the effect of flow rate, screen loading and the viscosity of

DEPENDABLE, CONVENIENT, ECONOMICAL

JOINTING

For Bell & Spigot Cast Iron WATER PIPE LINES

WEDGETITE

Thiokol plasticized sulphur base compound • Wafer form. No breaking up ingots; no powder, dust or dirt • 50 lb. fibre cartons • Quick melting. No caulking. Self sealing • Impervious to moisture so may be stored in the open • Unaffected by sulphur oxidizing bacteria • Applied with asbestos runner and "pouring gate"

For Vitrified Bell & Spigot SEWER PIPE

DURO-SEAL

Asphalt base compound • Inert to acids, alkalis, water, sewage • Stays flexible at low temperatures to allow settling in line.

WEDGETITE and DURO-SEAL are used by many municipalities under every kind of climatic condition.

Write for illustrated literature • Look to us for expert help with your jointing problems.

ELectro CHEMical
ENGINEERING & MFG. CO.
758-A Broad Street • Emmaus, Pa.

6 Reasons why

WALKING BEAM FLOCULATION

is now specified by water works engineers

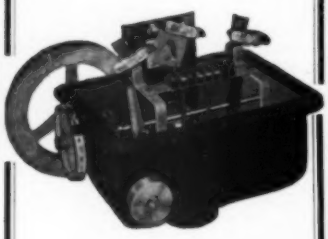
1. Eliminates troublesome underwater bearings.
2. Eliminates expensive dry well construction.
3. All bearings accessible for inspection and lubrication.
4. Produces quick responsive floc formation.
5. Longer filter runs.
6. A saving in alum.

Having no underwater bearings, Walking Beam Floculation equipment has been in continuous day and night operation for over 5 years. No time out for repairs.

Write today for Bulletin 451 and a list of water purification plants that have gone modern.

STUART CORPORATION
516 N. CHARLES ST., BALTIMORE 1, MD.

ROTO-TROL



RF-2

WITH ALTO-TROL

This 2-pump RF-2 Roto-Trol assures equal use and wear of both pumps. Each pump is operated on alternate starting cycles. The RF-2 operates both pumps together, when required. RF-2 installations give dependable service year after year, with the minimum of attention.

Write for full data

WATER LEVEL CONTROLS DIVISION
HEALY-RUFF COMPANY
783 HAMPDEN AVE., ST. PAUL 4, MINN.

WILKINSON LINE LOCATOR

The original—the pace setter

Built to QUALITY standards

Choice of discriminating buyers everywhere

Buy Satisfaction —not 'first cost'

Get the facts first

Locates all parts of your underground system

WILKINSON PRODUCTS CO.
3987 Chevy Chase Drive
Pasadena 3, California

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

fluid on pressure drop. Specifications for each type are also given.

Sewage Pumps

419

American Well Works, Aurora, Ill., has available a bulletin on **Sewage Pumps.**

The bulletin covers both Horizontal and Vertical type pumps. Exact specifications are given for each of these pumps. The next 8 pages are filled with capacity rating tables on these pumps giving the Total Dynamic Head in Feet of Water, RPM's, and the Capacity of U.S. Gallons per Minute.

Mechanical drawings of the pumps and accompanying charts giving complete dimensions complete the bulletin.

Gas Analyzer System

420

Minneapolis-Honeywell Regulator Co., Brown Instruments Division, Philadelphia, Pa., has just published an Instrumentation Data Sheet on the New **Davis Combustible Gas Analyzer System.**

The data sheet describes a new thermocouple type analyzer which uses Brown ElectroniK potentiometers for combustible gas analysis.

Built by Davis Emergency Equipment Company, the instruments reduce zero drift to negligible proportions. The data sheet describes fully the operation, application to the sewage field, and design features of the new analyzer. Illustrations showing the instruments and diagrams showing its operation are included in the four-page sheet.

Water Systems Counsel

421

Pittsburgh Pipe Cleaner Co., Pittsburgh, Pa., has just published a 2-color, 4-page folder on **The Pittsburgh Service for Water and Waste Water Systems.**

The folder outlines briefly the services, counsel and engineering skill offered by the company to aid in getting highest efficiency from waste and sewage systems. According to the folder, the company handles the whole operation—engineering surveys, field testing, laboratory analyses, design data, construction drawings and specifications, construction and operation.

Hydraulic Institute Standards

422

Hydraulic Institute, New York, N.Y., has announced the completion

ANOTHER CEMENT GUN CO. PRE-STRESSED WATER TANK

We built the above pre-stressed "GUNITE" tank in 1944. It is 90' in diameter with a water depth of 25'. The wall and dome roof of this tank are all "GUNITE". This is just one of scores of similar tanks designed and built by us. We will be glad to discuss your tank needs with you and submit designs and estimates for your consideration. Our method of pre-stressing the hoop rods in the wall and in the dome ring assures a bottle-tight and crack free reservoir. Our 64-page bulletin C2400 describes this method of construction and also scores of other profitable uses of "GUNITE". A copy will be sent free upon request.

CEMENT GUN COMPANY
"GUNITE" CONTRACTORS
GENERAL OFFICES—ALLENTOWN, PENNA. U.S.A.
MANUFACTURERS OF THE CEMENT GUN

DEPENDABILITY.....

PROVED by LOW COST MAINTENANCE

Hundreds of installations giving many years service without replacement of parts proves the simple, rugged construction which has established the reputation of the BLACKBURN - SMITH PNEUMATIC SEWAGE EJECTOR for dependability under all conditions.

Capacities from 30 to 600 GPM in single or twin units.

Pump sewage 150 feet STRAIGHT UP once a minute without fail!

The BLACKBURN - SMITH EJECTOR has no screens to clog —no impellers to jam—no water-sealed compressors . . .

Representatives Wanted

THE BLACKBURN-SMITH MFG. CO., INC.
92 River St. • Hoboken, N.J.

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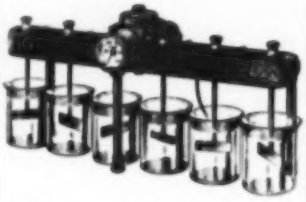
P & B Multiple Stirrer



When several samples are mixed simultaneously under identical conditions the optimum concentration of flocculent may be quickly selected and translated to plant quantities . . . The mixes takes 1,000 ml. beakers. Speeds from 10 to 100 r.p.m. are standard.

Write: **Cat. No. 77-700**

Phipps & Bird, Inc.

P. O. Box 2V **Richmond 5, Va.**

COLLECT SAMPLES

Automatically... Continuously!

Omega Sampler is a pump designed specifically for precision sampling in water, sewage, and industrial wastes plants.

FEATURES

Adjustable • Non-clogging
Positive displacement
Double pump head — collects two samples simultaneously
Renewable pump element • Corrosion resistant
Stainless steel mechanism

Whether you're sampling water, wastes, sewage, slurries, or process liquids, Omega Sampler will do the job accurately, dependably, automatically.

•

For complete information and Bulletin 67-H1A, Address Omega Machine Company (Division of Builders Iron Foundry), 350 Harris Ave., Providence 1, Rhode Island.

OMEGA

THE LAST WORD IN FEEDERS

of a new **Data Section for the Institute Standards.** The new Section included authoritative tables on the friction losses in Schedule 40 inside diameter steel pipe and in standard asphalt dipped cast iron pipe for both turbulent and laminar flow. The tables are easy to use, and an explanatory text with several illustrative examples is provided. The latest data on the loss in valves and fittings is included, and will be of widespread interest.

This new Data Section will also include tables on the properties of water, steel and cast iron pipe, tables for the friction loss of paper stock in cast iron pipe, and recommended materials for pumping various liquids.

Laboratory and Test Equipment

423

LaMotte Chemical Products Co., Towson, Maryland, has available a 4-page Service Bulletin listing **Laboratory and Test Equipment.**

The bulletin covers: Fluoride determination test kit; Reagents for determining total hardness of water by direct colorimetric titration; the LaMotte Filtr-Ion; pH equipment; Alkali and Alkalinity test kits; laboratory aids and Soil testing apparatus.

Concrete Pipe Coating

424

Hamilton Kent Manufacturing Co., Kent, Ohio, has just made available a two-color, four-page bulletin on **Rexon Coating No. 2.**

The bulletin describes completely the properties and uses of Rexon, the chemically resistant concrete pipe coating. According to the bulletin, it was specifically developed to protect concrete pipe against the chemical attack of sewage and industrial wastes. It is said to be virtually inert to all acids, alkalies, oils and solvents.

ANTHRAFILT

Trade Mark Reg. U. S. Patent Office

A Filter Medium For All Purposes

ANTHRACITE EQUIPMENT CORP.

Anthracite Institute Building
Wilkes-Barre, Pa.

All correspondence regarding sales and engineering should be addressed to:

PALMER FILTER EQUIPMENT CO.

822 E. 8th St. Erie, Pa.

Engineers and Sales Agents

INSURE YOUR FILTER
AT NO COST
by using our
FILTER SAND and GRAVEL
FOR WATER AND SEWAGE PLANTS

Close attention to detail by experienced men and new modern equipment insure both the quality and prompt shipment of all orders. Our method of shipping in bulk prevents mixing of sizes in transit.

SHIPMENT IN BAGS WHEN PREFERRED

Try us on your next order.

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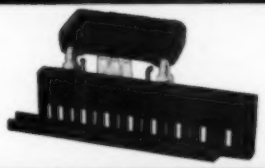
NORTHERN GRAVEL COMPANY

P. O. Box No. 307, Muscatine, Iowa

GUARANTEED pH & CHLORINE COLOR STANDARDS



...with Taylor Comparators *simplify* water treatment

Every Taylor Comparator comes to you with a full set of liquid color standards that carry an *unlimited guarantee against fading.* Moreover, each complete set of color standards is mounted in a sturdy plastic slide, thus eliminating the need for handling fragile single standards.

They are easy to use, give accurate results in a matter of seconds. Each set is complete with slide, base, reagents and accessories, also complete instructions.

SEE YOUR DEALER.

FREE HANDBOOK

Gives theory and application of pH and chlorine control, illustrates and describes all Taylor sets. Write for your copy today.

W. A. TAYLOR AND CO.

7308 YORK RD. • BALTIMORE 4, MD.

If interested in equipment or literature mentioned above, mail a Reader Service Card with your name, address, and item key number.

6 Reasons why

PALMER SURFACE WASH SYSTEMS

are specified by water works engineers

1. Prevent Sand Beds From Cracking.
2. Eliminate Mud Balls.
3. Save Wash Water.
4. Lengthen Filter Runs.
5. Higher Rates of Filtration.
6. Better Tasting Water.

Having no underwater bearings, Walking Beam Flocculation equipment has been in continuous day and night operation for over 5 years. No time out for repairs.

Write today for Bulletin 451 and a list of water purification plants that have gone modern.

STUART CORPORATION
316 N. CHARLES ST., BALTIMORE 1, MD.

LEADITE

The Pioneer Self Caulking Material for C. I. Pipe

Thousands of miles are—

Jointed with **LEADITE** for **Satisfaction and Long Life**

because Leadite makes a good, tight joint that improves with age . . . and in addition, saves on installation costs.

Write for Literature.

THE LEADITE COMPANY
Girard Trust Co. Bldg., Philadelphia 2, Pa.

No Caulking

Characteristics, working properties and methods of application of this air drying, self vulcanizing coating are also contained in the bulletin.

Vane Type Rotary Pump

425

Worthington Pump and Machinery Corporation, Harrison, N.J., has announced a bulletin on a new **Heavy Duty, Vane Type Rotary Pump.**

The 4-page bulletin pictures and describes the six models of the pump in 8 sizes. They include pipe openings from 2 to 12 suction inches, and 2 to 10 discharge inches. The range of nominal ratings includes capacities from 25 to 1,000 gpm and speeds from 850 to 210 rpm. Dimensions, nominal ratings and line drawings of the pumps are also included.

Telemetering System

426

Minneapolis-Honeywell Regulator Co., Brown Instruments Division, Philadelphia, Pa., has just issued an instrumentation data sheet on **Improved Westinghouse Telemetering System Employs ElectroniK Recorder.**

The data sheet describes the Westinghouse Freq-O-Tron telemetering equipment as used with Brown ElectroniK recorders for long distance telemetering and high speed transmission of system variables to a central location. Also the sheet discusses the telemetering system requirements, general field application, method of operation and salient design features of the Freq-O-Tron equipment.

Photographs of this equipment, block diagrams of the system components, and line diagram for single station telemetering are included.

Pipe Line Supplies

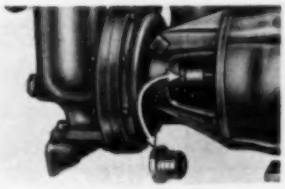
427

R. H. Baker & Company Inc., Huntington Park, Calif., has available a catalog covering the company's line of **Pipe Line Supplies and Specialties.**

The catalog covers CirclSeal Clamps, Fittings, Flexible Pipe Couplings, Bolted Couplings, Meter Couplings, Tees and Crosses, Pipe Repair Clamps, Repair Sleeves, and Pipe Saddles.

One section of the catalog is devoted to Baker AllCopper Fittings for Cement Asbestos Pipe. These Threaded Risers, Ells, Tees, Reducers and Crosses are shown and described. Sizes and specifications are also given.

Troubled with Leaky Stuffing Boxes on Your Pumps?



SYNTRON

SHAFT SEALS

—provide fully automatic, self-adjusting sealing action. Self-contained, self-lubricating, easy to install units, they are easy on power, easy on shafts. Seal in liquids or gases. Special seals for corrosive or abrasive liquids.

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SYNTRON CO.
660 Lexington Ave. Homer City, Pa.

MORE SECURITY FOR YOUR MONEY

- Galvanized fence fabric
- Heavy post caps and arms
- Snug-fitting couplings
- Sturdy line posts
- Improved, welded gates
- Extra post and rail ties
- Engineered erection

*Trade Mrks Reg. U.S. Pat. Off.

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Consulting Engineers

SPECIALIZING IN THE FIELD OF

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Consulting Engineers
Water, Sewage and Industrial Waste Problems — Airfields, Refuse Incinerators, Power Plants—Industrial Buildings City Planning—Reports—Valuations Laboratory
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BLACK & VEATCH
Consulting Engineers
Water — Sewage — Electricity Industry
Reports, Design, Supervision of Construction, Investigations, Valuation and Rates
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CAPITOL ENGINEERING CORPORATION
Engineers—Constructors—Management
SEWAGE SYSTEMS — Designs and Surveys, Planning, Bridges
WATER WORKS — Roads and Streets, Airports, Dams
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DILLSBURG, PENNSYLVANIA

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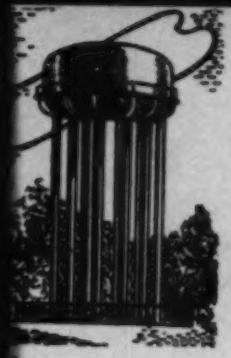

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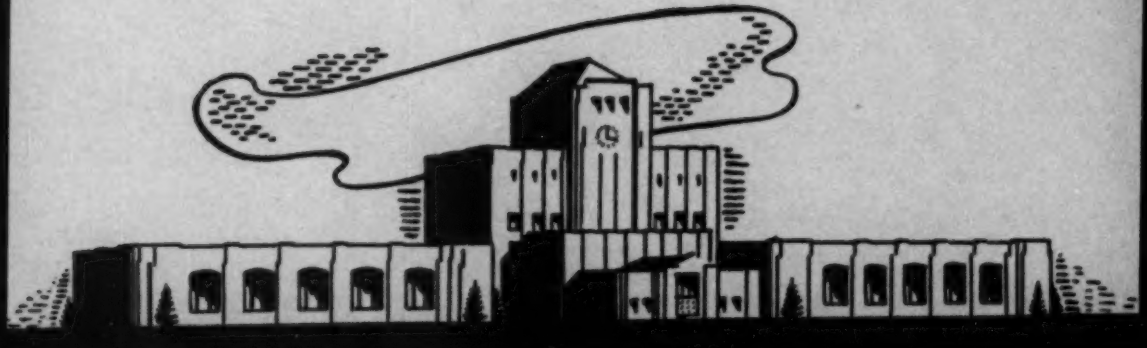

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Cast Iron Pipe Research Assoc., 122 So. Michigan Ave., Chicago.
Central Foundry Co., 386 Fourth Ave., New York, N. Y.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
The Filer & Stowell Co., 147 E. Becher St., Milwaukee 7, Wis.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hardinge Mfg. Co., 240 Arch St., York, Pa.
Lee Hydraulic Co., P.O. Box 804, Troy, N. Y.
Posey Iron Works, Inc., Lancaster, Pa.
Richmond Fdry. & Mfg. Co., P.O. Box 5150, Saunders Sta., Richmond, Va.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5.

CAST IRON PIPE
(See Pipe)

CATCH BASIN CLEANERS
(Vacuum Type)
Rootes Motors, Inc., 27-11 Bridge Plaza, Rd., Long Island City 1, N.Y.

CATHODIC PROTECTIVE SYSTEMS
Chicago Bridge & Iron Co., 332 South Michigan Ave., Chicago.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Electro Rust-Proofing Corp. (N. J.), Belleville, N. J.
H. D. Fowler Co., Inc., 901 Lane St., P.O. Box 3084, Seattle, Wash.

CAULKING MACHINES & TOOLS
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Mueller Co., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.

CEMENT ASBESTOS PIPE
H. D. Fowler Co., Inc., 901 Lane St., (P. O. Box 3084), Seattle, Wash.
Johns-Manville, 22 E. 40th St., New York City.
Keasbey & Mattison Co., Ambler, Pa.

CEMENT GUN
Cement Gun Co., Inc., 1520 Walnut Street, Allentown, Penna.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

CEMENT PIPE
(See Pipe, Concrete)

CEMENT LINED PIPE
(See Pipe, Cement Lined)

CEMENT LINING OF PIPE
Centriline Corp., 140 Cedar St., New York 6, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CEMENTS, ACID PROOF & ALKALI PROOF
Atlas Mineral Prod. Co., Mertztown, Pa.
Electro-chemical Engr. & Mfg. Co., Broad and Grant Sts., Emmaus, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.
U. S. Stoneware Co., Akron 9, Ohio.

CEMENTS, REFRACTORY
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

CEMENTS, SEWER PIPE
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York, N. Y.
Northrup & Co., Inc., Spring Valley, N. Y.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

CEMENTS, WATER MAINS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York, N. Y.
Michael Hayman & Co., 870 E. Ferry St., Buffalo, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CHAINS (Elevating, Conveying and Power Transmission)
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 46, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

CHEMICAL CONTROL EQUIP.
(See Laboratory Apparatus and Reagents)

CHEMICAL, CONVEYING EQUIPMENT
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., 4079 E. 116th St., Cleveland 5, Ohio.
Hardinge Co., Inc., 240 Arch St., York, Pa.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 46, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CHEMICAL FEEDING AND PROPORTIONING EQUIPMENT (Dry and Solution—Also see Chlorinators)
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P.O. 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Infilco, Inc., Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
F. B. Leopold, 2413 W. Carson St., Pittsburgh 4, Pa.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Omega Machine Co., 345 Harris Avenue, Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Roots-Connersville Blower Corp., P.O. Box 327, Connersville, Ind.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
R. W. Sparling, Box 3277, Terminal Annex, Los Angeles, Calif.
Syntron Co., 650 Lexington, Homer City, Pa.
Wallace and Tiernan, Newark 1, New Jersey.

CHLORINATORS
(See also Hypochlorinators)
Amer. Water Softener Co., Philadelphia 33, Pa.
Builders - Providence, Inc., 350 Harris Ave., Providence, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Infilco, Inc., Tucson, Ariz.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Omega Machine Co., 345 Harris Ave., Providence 1, R. I.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Wallace and Tiernan, Newark 1, New Jersey.

CHLORINATORS (Cleaning Solutions)
Lake Products Co., Inc., 6576 Oleatha Ave., St. Louis 9, Mo.

CHLORINE DIOXIDE
(See Sodium Chlorite)

CHLORINE, LIQUID
Diamond Alkali Co., 300 Union Commerce Bldg., Cleveland 14, Ohio.
John Wiley Jones Co., Caledonia, N. Y.
Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Md.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Solvay Sales Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.

CHLORINE CONTROL EQUIPMENT
(See Residual Chlorine Control)

CLAMPS AND SLEEVES, PIPE
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

CLAMPS, BELL JOINT
Carson-Cadillac Corp., 1221 Pinson St., Birmingham, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.

CLAMPS, PIPE REPAIR
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.

CLARIFIERS, SEWAGE AND WATER
American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Cochrane Corp., 17th St. and Allegheny Ave., Philadelphia, Pa.
Dorr Co., Barry Place, Stamford, Conn.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Brothers Co., 1423 N Dayton St., Chicago 22, Ill.

CLAY PIPE
(See Vitrified Clay Pipe and Products)

CLEANERS, CATCH BASIN
(See Catch Basin Cleaners)

CLEANING COMPOUNDS
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
General Chem. Div., 40 Rector St., New York 6, N. Y.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
Solvay Sales Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.

CLEANING SEWAGE MAINS
(See Sewer Cleaning Equipment and Service)

CLEANING WATER MAINS
Ace Pipe Cleaning Contractors, Inc., 2062 Indiana Ave., Kansas City 1, Mo.
Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.

National Water Main Cleaning Co., 50 Church St., New York City.
Pittsburgh Pipe Cleaner Co., 133 Dahlem St., Pittsburgh 6, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

CLEANING SOLUTIONS, CHLORINATORS
(See Chlorinators, Cleaning Solutions)

COAGULATING AIDS
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.

COAL AND ASH HANDLING MACHINERY
(See Ash and Coal Handling Machinery)

COATINGS, ACID AND ALKALI-PROOF
Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Atlas Mineral Products Co., Mertztown, Pa.
Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Electro-chemical Engr. & Mfg. Co., Broad and Grant Sts., Emmaus, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
Haynes Products Co., 4007 Farnam St., Omaha 3, Nebr.
Inertol Co., Inc., 480 Frelinghuysen Ave., Newark 5, N. J.
Johns-Manville Corp., 22 East 40th St., New York 16.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.
U. S. Stoneware Co., Akron 9, Ohio.

COATINGS AND LININGS
(See Bituminous Coatings and Linings)

COCKS (Curb, Meter, Corporation, Etc.)
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Glauber Brass, Inc., Kinsman, Ohio.
Hays Mfg. Co., 12th and Liberty Sts., Erie, Pa.
A. Y. McDonald Mfg. Co., 12th and Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.

COLLECTORS (Sludge)
(See Sludge Collectors)

COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.

COMMINUTORS
(See Grinders also)
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Worthington Pump and Machinery Corp., Harrison, N. J.

COMPARATORS, COLOR
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Hellige, Inc., 37-18 Northern Blvd., Long Island City, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.
Wallace and Tiernan, Newark 1, N. J.

COMPOUNDS, SEWER JOINT
Atlas Mineral Prod. Co., Mertztown, Pa.
Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Electro-chemical Engr. & Mfg. Co., Broad and Grant Sts., Emmaus, Pa.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Hydraulic Development Corp., 50 Church St., New York City.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.
Northrop & Co., Inc., Spring Valley, N. Y.

COMPRESSORS, AIR
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Davey Compressor Co., Kent, Ohio.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Roots-Connersville Blower Corp., P.O. Box 327, Connersville, Ind.
Standard Stoker Co., Erie, Pa.
Worthington Pump and Machinery Corp., Harrison, N. J.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

CONCRETE BREAKERS
Homelite Corp., Port Chester, N. Y.
Syntron Co., 650 Lexington, Homer City, Pa.
Worthington Pump and Machinery Corp., Harrison, N. J.

CONCRETE HARDENER
Diamond Alkali Co., Pittsburgh.
Dow Chemical Co., Midland, Mich.
Haynes Products Co., 4007 Farnam St., Omaha 3, Nebr.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.

CONCRETE MIXER
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, Ohio.

CONCRETE PIPE
Lock-Joint Pipe Co., P.O. Box 269, East Orange, N. J.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

CONCRETE SAWS
(See Saws, Concrete and Masonry)

CONDENSERS (Steam)
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
R. D. Cole Mfg. Co., Newnan, Ga.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.
Worthington Pump and Machinery Corp., Harrison, N. J.

CONTRACTORS (Water and Sewage Works)
Cement Gun Co., P.O. Box 424, Allentown, Pa.
Hammond Iron Works, Warren, Pa.
Layne & Bowler, Inc., Box 6818, Hollywood Sta., Memphis 8, Tennessee.
Municipal Service Co., Dept. M. 3, 908 Grand Avenue, Kansas City, Mo.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CONTROLLERS, FLOW, LEVEL, PRESSURE, TEMPERATURE
Automatic Control Co., 1005 University Avenue, St. Paul 4, Minnesota.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders - Providence, Inc., 250 Harris Ave., Providence, R. I.
Fischer & Porter Co., Dept. 9-F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Infilco, Inc., Tucson, Ariz.
Leupold & Stevens Inst., 4445 N. E. Glisan, Portland, Ore.
Lumenite Electronic Co., 407 So. Dearborn, Chicago, Ill.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Pike Hoffman Control Co., 272 E. 5th St., St. Paul, Minn.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

CONVEYORS AND CONVEYING EQUIPMENT
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., 4079 E. 116th St., Cleveland 5, Ohio.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Omega Machine Div., 845 Harris Ave., Providence 1, R. I.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Syntron Co., 650 Lexington, Homer City, Pa.

COPPER, BRASS, BRONZE
The American Brass Co., 25 Broadway, New York 4, N. Y.
Glauber Brass, Inc., Kinsman, Ohio.
Hays Mfg. Co., Erie, Pa.

COPPERAS (Sulfate of Iron)
Phelps Dodge Refining Corp., 40 Wall St., New York, N. Y.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

COPPER SULFATE
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6.
Phelps Dodge Refg. Corp., 40 Wall St., New York, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Tennessee Corp., 1028 Connecticut Ave., N.W., 823-A, Washington, D. C.

COPPER TUBE
The American Brass Co., 25 Broadway, New York 4.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hays Mfg. Co., 12th and Liberty Sts., Erie, Pa.
Mueller Co., Decatur 70, Ill.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.

CORPORATION & CURB COCKS (See Cocks-Corporation, Curb and Meter)

CORROSION SUPPRESSION
Calgon, Inc., Hagan Bldg., 323 4th Ave., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.

COUPLINGS & CONNECTIONS, PIPE
James P. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Glauber Brass, Inc., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., 12th and Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Carro Gordo St., Decatur 70, Ill.

COUPLINGS, FLEXIBLE
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 4, Ohio.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

COVERS, HANDHOLE, MANHOLE, SAMPLING
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12.
The E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.
Warren Fdry. & Pipe Corp., 11 Broadway, New York, N. Y.

CULVERT CLEANERS
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.

CULVERT PIPE
(See Pipe, Culvert)

CURB BOXES
Central Foundry Co., Murray and Pacific Sts., Newark, N. J.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Hays Mfg. Co., 12th and Liberty Sts., Erie, Pa.
A. Y. McDonald Mfg. Co., 12th and Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Verako Products, Inc., Grand Ave. and Skokie Rd., Waukegan, Ill.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

DECHLORINATING EQUIPMENT AND CHEMICALS
American Water Softener Co., Philadelphia 33, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
General Chemical Co., 40 Rector St., New York, N. Y.
Infilco, Inc., Tucson, Ariz.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Wallace and Tiernan, Newark 1, New Jersey.

DE-MINERALIZATION EQUIPMENT (Water)
American Well Works, 100 N. Broadway, Aurora, Ill.
Chem. Equipment Co., P. O. Box 3098, Term. Annex, Los Angeles 54, Calif.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., Tucson, Ariz.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.

DIAPHRAGM, PUMP
(See Pumps, Diaphragm)

DIATOMITE FILTER SEPTUMS
Carborundum Co., Perth Amboy, N. J.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Proportioneers, Inc., 345 Harris Ave., Providence, R. I.

DIESEL ENGINES
(See Engines, Diesel)

DIFFUSERS—PLATES, TUBES AND FITTINGS
Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equipment, Inc., Aurora, Ill.

DIGESTER EQUIPMENT (Sludge)
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Hardinge Co., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

DISTRIBUTORS (Sewage Filter)
American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Infilco, Inc., Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

DRAINS, GUTTER, FLOOR
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
A. Y. McDonald Mfg. Co., 12th and Pine Sts., Dubuque, Iowa.

DRILLING AND BORING EQUIPMENT
Bucyrus-Erie Co., South Milwaukee, Wis.
Hydraulic Corp., Ltd., 116 New Montgomery St., San Francisco.

DRIVES, CHAIN
(See Chains)

DRIVES, RIGHT ANGLE GEAR
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Payne Dean Co., Madison, Conn.
Worthington Pump and Machinery Corp., Harrison, N. J.

DRIVES, V-BELT
Allis-Chalmers Mfg. Co., 1192 So. 70th St., Milwaukee, Wis.
Worthington Pump and Machinery Corp., Harrison, N. J.

DRY CHEMICAL FEEDERS
(See Chemical Feeding Equipment)

DRYING SYSTEMS (Sludge)
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
R. D. Cole Mfg., Newnan, Ga.
Combustion Engineering - Superheater, Inc., 200 Madison Ave., New York, N. Y.
Dorr Co., Barry Place, Stamford, Conn.
Gen. Amer. Transp. Co., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N. Y.
Nichols Engineering & Research Corp., 70 Pine St., New York 5.
Posey Iron Works, Inc., Lancaster, Pa.

EARTH BORING TOOLS
Hydraulic Corp., Ltd., 681 Market St., San Francisco 5, Calif.

EARTH MOVING EQUIPMENT
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Bucyrus-Erie Co., South Milwaukee, Wis.

EJECTORS, PNEUMATIC or STEAM (For Sewage and Sludge)
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
H. D. Fowler Co., Inc., 901 Lane St., Seattle, Wash.
Posey Iron Works, Inc., 560 So. Prince St., Lancaster, Pa.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.
Worthington Pump and Machinery Corp., Harrison, N. J.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

ELECTRICAL CONTROL EQUIPMENT
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Automatic Control Co., 1005 University Ave., St. Paul, Minn.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
General Electric Corp., Schenectady, N. Y.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Lumenite Electronic Co., 407 So. Dearborn St., Chicago, Ill.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

ELECTRICAL TESTING EQUIPMENT
Simmson Electric Co., 5200 West Kinzie St., Chicago 44, Ill.

ELECTRICALLY OPERATED GATE VALVES
(See Valves, Motor Operated)

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment)

ENGINE-GENERATOR UNIT
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Climax Engine & Pump Mfg. Co., 208 South La Salle Street, Chicago 4, Illinois.
Davey Compressor Co., Kent, Ohio.
W. S. Darley & Co., 2910 Washington Blvd., Chicago 12, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Riverdale Ave., Port Chester, N. Y. (Gasoline Engine Driven and Portable)
Westinghouse Electric Corp., Pittsburgh 30, Pa.
Worthington Pump and Machinery Corp., Harrison, N. J.

ENGINES DIESEL
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Worthington Pump and Machinery Corp., Harrison, N. J.

ENGINES, DUAL FUEL
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Worthington Pump and Machinery Corp., Harrison, New Jersey.

ENGINES (Gas & Gasoline)
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Climax Engine & Pump Mfg. Co., 208 South La Salle Street, Chicago 4, Illinois.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Worthington Pump and Machinery Corp., Harrison, New Jersey.

ENGINES, SLUDGE GAS
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Climax Engine & Pump Mfg. Co., 208 South La Salle Street, Chicago 4, Illinois.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Worthington Pump and Machinery Corp., Harrison, New Jersey.

EXPANSON JOINTS—PIPE
(See Joints—Expansion, Pipe)

EXHAUSTERS, AIR
(See Pump, Vacuum)

FANS, EXHAUST AND VENTILATNG
Dracco Corp., 4079 E. 116th St., Cleveland 5, O.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

FEED, CHEMICAL
(See Chemical Feeding Equipment)

FEED WATER FILTERS
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Worthington Pump and Machinery Corp., Harrison, N. J.

FEED WATER HEATERS
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Carborundum Co., Refractories Div., Perth Amboy, N. J.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Worthington Pump and Machinery Corp., Harrison, N. J.

FENCE (Chain Link)
Continental Steel Corp., Kokomo, Ind.

FERRIC CHLORIDE
Dow Chemical Co., Midland, Mich.
Penn. Salt Mfg. Co., 100 Widener Bldg., Philadelphia 7, Pa. (Liquid)
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

FERRIC CHLORIDE FEEDERS
(See Chemical Feed and Proportioning Equipment)

FERRIC SULPHATE
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Tennessee Corp., 1028 Connecticut Ave., N.W. 823-A, Washington, D. C.

FIBRE PIPE
(See Pipe, Fibre)

FILTER ALBUM
Activated Alum Sales Corp., 316 Wyndhurst Ave., Baltimore 10, Md.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Penn Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

FILTER EQUIPMENT
American Well Works, 100 N. Broadway, Aurora, Ill.
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
R. D. Cole Mfg., Newnan, Ga.
Carborundum Co., Refractories Div., Perth Amboy, N. J.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
U. S. Hoffman Mach. Corp., 111 Fourth Ave., New York 3, N. Y.
Walker Process Equip. Co., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

FILTER MEDIA
Anthracite Equipment Co., Wilkes-Barre, Pa.

FILTER PLATES AND TUBES
Carborundum Co., Perth Arboy, N. J.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.

FILTER RATE CONTROLLERS & GAGES
(See Rate Controllers.)

FILTERS, SAND & GRAVEL
Graver Water Conditioning Co., 216 West 14th Street, New York, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh, Pa.
The Permutit Co., 330 W. 42nd Street, New York 18, N. Y.

FILTER UNDERDRAINS, SEWAGE
American Well Works, 100 N. Broadway, Aurora, Ill.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisson, Portland, Ore.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

FILTER UNDERDRAINS, WATER
Amer. Well Works, 100 N. Broadway, Aurora, Ill.
The Carborundum Co., Perth Amboy, N. J.

Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Nat'l. Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago 2, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore, Md.
Walker Process Equipment, Inc., Aurora, Ill.

FILTERS VACUUM

U. S. Hoffman Machinery Corp., 111 Fourth Ave., New York 3.

FILTER WASH CONTROL

Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.

FITTINGS, PIPE, SOLDER TYPE

The American Brass Co., 25 Broadway, New York 4, New York.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 240 W. Exchange St., Providence 1, R. I.
Hays Mfg. Co., Erie, Pa.
Lock Joint Pipe Co., P. O. Box
Johns-Manville Corp., 22 East 40th St., New York 16.
269, E. Orange, N. J.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

FITTINGS, TEES, ELLS, ETC.

American Cast Iron Pipe Co., P. O. Box 2603, Birmingham 3, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Glauber Brass, Inc., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
The Kennedy Valve Mfg. Co., 1036 E. Water St., Elmira, N. Y.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.

FLASH MIXING EQUIPMENT

(See Mixers & Mixing Equipment.)

FLEXIBLE JOINTS

(See Joints, Flexible Pipe.)

FLOATING COVERS (Digester)

Ralph B. Carter, 192 Atlantic St., Hackensack, N. J.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip., Inc., Aurora, Ill.

FLOCCULATING EQUIPMENT

American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Dorr Co., Barry Place, Stamford, Conn.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 18, Ohio.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelhpia, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Process Engineers, Inc., 821 Market St., San Fancisco 3, Calif.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore, Md.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

FLOOR STANDS

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve Co., Williamsport, Pa.
The Filer & Stowell Company, 147 E. Becher Street, Milwaukee 7, Wisconsin.
Infilco, Inc., Tucson, Ariz.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
F. B. Leopold Co., 2413 W. Carson St., Pittsburgh 4, Pa.
Mueller Co., 2561 Chestnut St., Chattanooga, Tenn.
M & H Valve & Fittiings Co., P. O. Box 909, Anniston, Ala.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.

FLOORING, GRIDS, GRATINGS, TREADS, ETC.

Blaw-Know Company, 2051 Farmers Bank Bldg., Pittsburgh 22, Pa.
Irving Subway Grating Co., Inc., 27th St., 49th and 51st Aves., Long Island City 1, N. Y.

FLOW METERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Builders-Providence, Inc., 345 Harris Ave., Providence, R. I.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.

FLOW RECORDERS

(See Rate of Flow Recorders)

FLOW REGULATORS

(See Rate of Flow Controllers)

FLOW TUBES

Builders-Providence, Inc., 345 Harris Ave., Providence, R. I.
Foster Engineering Co., 835 Lehigh Avenue, Union, N. J.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

FLUMES, IRON & STEEL

R. D. Cole Mfg. Co., Newnan, Ga.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

FLUORIDATION CHEMICALS

Blockson Chemical Co., P. O. Box 1407 Joliet, Ill.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Tennessee Corp., 1028 Connecticut Ave., N.W. 823-A, Washington, D. C.

FLUORIDATION EQUIPMENT

Omega Michine Co., 345 Harris Ave., Providence, R. I.
Proportioneers, Inc., 345 Harris Ave., Providence, R. I.
Wallace & Tiernan, Newark, N. J.

FOOT VALVE WITH STRAINER

(See Valves, Foot)

FORMS & GASKETS FOR PIPE JOINTS

Northrup & Co., Inc., Spring Valley, N. Y.

FURNACES, MELTING, POURING LADLES, POTS, ETC.

Atlas Mineral Products Co., Mertztown, Pa.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Lee Hydraulic Co., P. O. 804, Troy, N. Y.
Michael Hayman & Co., Inc., 870 E. Ferry St., Buffalo, N. Y.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Joseph G. Pollard Co., Inc., New Rhode Park, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

GAGES (Liquid Level, Pressure Recording)

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
The Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glissen, Portland, Ore.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
Williams Gauge Co., 1620 Penn. Ave., Pittsburgh 12, Pa.

GARBAGE GRINDERS

(See Grinders)

GAS DIFFUSERS

Carborudum Co., Perth Amboy, N. J.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip., Inc., Aurora, Ill.

GAS ENGINES

(See Engines, Gas)

GATES, FENCE (Steel)

Continental Steel Corp., Kokomo, Ind.

GAS HOLDERS

American Well Works, 100 N. Broadway, Aurora, Ill.
Chicago Bridge & Iron Company, 332 S. Michigan Ave., Chicago.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
R. D. Cole Mfg. Co., Newnan, Ga.
The Dorr Company, Barry Place, Stamford, Conn.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Hammond Iron Works, Warren, Pa.
Infilco, Inc., Tucson, Ariz.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25.
Posey Iron Works, Inc., Lancaster, Pa.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip., Inc., Aurora, Ill.

GAS INDICATOR AND DETECTORS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.

GATES, SHEAR

Chapman Valve Mfg. Co., 203 Hampshire St., ndian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
Mueller Co., Decatur 70, Ill.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.

GATES, SLUICE

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
R. D. Cole Mfg., Newnan, Ga.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wis.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
Mueller Co., Decatur 70, Ill.
R.S. Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

GATE VALVE OPERATOR

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve and Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
Payne Dean & Co., Madison, Conn.
A. P. Smith Mfg. Co., E. Orange, N. J.

GATE VALVES

(See Valves, Gate)

GEARS, SPEED REDUCING

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
De Laval Steam Turbine Co., Nottingham Way, Tranton 2, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.
Worthington Pump and Machinery Corp., Harrison, N. J.

GEIGER COUNTERS

Beckman Instruments, Inc., 820 Mission St., South Pasadena, Calif.

The Detectron Co., 1651 Cahuenga Blvd., North Hollywood, Calif.
The Goldak Co., 1544 W. Glenoaks Blvd., Glendale 1, Calif.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

GENERATORS
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
General Electric Co., Schenectady, N. Y.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.
Worthington Pump and Machinery Corp., Harrison, N. J.

GENERATOR SETS, GAS & DIESEL ENGINES
(See Engine Generating Units)

GOOSENECKS
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Glauber Brass, Inc., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
Worthington Pump and Machinery Corp., Harrison, N. J.

GRATINGS (See Flooring)

GREEN SAND (See Zeolite)
Amer. Water Softener Co., Philadelphia 33, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Graver Water Conditioning Co., 216 West 14th Street, New York, N. Y.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar, New York 6, N. Y.

GRINDERS, GARBAGE & SCREENINGS
Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Ill.
Dorr Co., Barry Place, Stamford, Conn.
General Electric Co. (household), Bridgeport, Conn.
Given Manufacturing Co., 3301 E. Fruitland, Los Angeles 58, Calif.
Infilco, Inc., Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Walker Process Equipment, Inc., Aurora, Ill.
Westinghouse Elect. Corp. (household), Pittsburgh, Pa.
Worthington Pump and Machinery Corp., Harrison, N. J.

GRIT CHAMBER EQUIPMENT & GRIT WASHERS
American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Ill.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2945 W. Hunting Park Ave., Philadelphia 40, Pa.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip., Inc., Aurora, Ill.

GROUND KEY STOPS
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
The Ford Meter Box Co., Inc., Wabash, Ind.
Glauber Brass, Inc., Kinsman, Ohio.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
The Welsbach Corp., Kitson Division, 1500 Walnut Street, Philadelphia 2, Pa.

GUNITING CONTRACTNG
Cement Gun Company, Inc., 1520 Walnut Street, Allentown, Pa.

HEATERS, DIGESTER
American Radiator & Standard Sanitary Corp., Box 1226, Pittsburgh 30, Pa.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Ill.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., Tucson, Ariz.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip., Inc., Aurora, Ill.

HOSE, STEAM, AIR, WATER, SUCTON
The American Brass Co., 25 Broadway, New York 4, N. Y.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.

HYDRANT PUMPS
(See Pumps, Hydrant)

HYDRANTS (Fire)
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., 1936 E. Water St., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., Decatur 70, Ill.
Rensselaer Valve Co., Ontario, Street, Troy, N. Y.
Ross Valve Mfg. Co., Inc., Box 595, Troy, N. Y.
A. P. Smith Mfg. Co., E. Orange, N. J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.

HYDRAULICALLY OPERATED GATE VALVES
(See Valves, Gate)

HYDROGEN ION EQUIPMENT
(See pH Test Equipment)

HYPO-CHLORINATORS
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Omega Machine Co., 345 Harris Ave., Providence 1, R. I.
Precision Machine Co., 9 Union Square, Sommerville, Mass.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Wallace and Tiernan, Newark 1, N. J.

HYPOCHLORITES (High Test)
(See Calcium Hypochlorite)

INCINERATORS
Combustion Engineering - Superheater, Inc., 200 Madison Ave., New York, N. Y.
Dorr Co., Barry Place, Stamford, Conn.
Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N. Y.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED
Automatic Control Co., 1005 University Ave., St. Paul, Minn.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Leupold & Stevens Inst., 4445 N. E. Glisson, Portland, Ore.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

INSECTICIDES
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.

INSERTING SLEEVES, VALVE
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
A. P. Smith, 545 N. Arlington Ave., East Orange, N. J.

INSTRUMENTS (Meterological)
Leupold & Stevens Inst., 4445 N. E. Glissen, Portland, Ore.
Payne Dean and Co., Madison, Conn.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Wallace and Tiernan, Newark 1, N. J.

INSULATION
Johns-Manville, 22 E. 40th St., New York City.
National Gypsum Co., Buffalo, N. Y.

IRON SULFATE
(See Ferric Sulfate, or Ferrous Sulfate)

JOINTING COMPOUND AND MATERIALS
Atlas Mineral Prod. Co., Mertztown, Pa.
Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Electro-Chemical Engr. & Mfg. Co., Broad & Grant Sts., Emmaus, Pa.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Michael Hayman & Co., 870 E. Ferry St., Buffalo, N. Y.
Hydraulic Development Corp., 50 Church St., New York City.
Johns-Manville Corp., 22 East 40th Street, New York 16, N. Y.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Leadite Co., Philadelphia, Pa.
Northrop & Co., Inc., Spring Valley, N. Y.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.

JOINTS, EXPANSION—PIPE
James B. Clow, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Hamilton Kent Mfg. Co., 218 Gougler Ave., Kent, Ohio.
Johns-Manville Corp., 22 E. 40th Street, New York 16, N. Y.
Lock Joint Pipe Co., P. O. Box 269 East Orange, N. J.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.

JOINTS, FLEXIBLE PIPE
Hamilton Kent Mfg. Co., Kent, Ohio.
James B. Clow & Sons, 201-299 N. N. Talman Ave., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.

JOINTS, MECHANICAL FLEXIBLE
Amer. Brass Co., Waterbury, Conn.
Carson-Cadillac Corp., 1221 Pinsan St., Birmingham, Ala.
Central Foundry Co., Murray & Pacific Sts., Newark, N. J.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
The A. P. Smith Mfg. Co., East Orange, New Jersey.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City

JUTE, BRAIDED AND TWISTED
Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Electro-Chemical Engr. & Mfg. Co., Broad & Grant Sts., Emmaus, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hydraulic Development Corp., 50 Church St., New York City.
Michael Hayman & Co., Inc., 870 E. Ferry St., Buffalo, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

LABORATORY APPARATUS, REAGENTS AND EQUIPMENT
Central Scientific Co., 1700 Irving Park Rd., Chicago 13, Ill.
Coleman Instruments, Inc., 318 Madison St., Maywood, Ill.
Calgon, Inc., 323 4th Ave., Hagan Bldg., Pittsburgh, Pa.
Fisher Research Laboratory, Inc., 1961 University Ave., Palo Alto, Calif.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Klett Mfg. Co., 179 E. 87th St., New York 28, N. Y.
Nat'l Technical Labs., Los Angeles, Calif.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

LEAD, CAULKING
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.

LEAK LOCATING INSTRUMENTS
(See Water Leak Locating Instruments)

LIGHTING
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

LIMES, HYDRATED & QUICK
Dow Chemical Co., Midland, Mich.
National Gypsum Co., 325 Delaware Ave., Buffalo 2, N. Y.

LINING, TANKS
Electro-Chemical Engr. & Mfg. Co., Broad & Grant Sts., Emmaus, Pa.

LIQUID CHLORINE
(See Chlorine, Liquid)

LOCATORS, BOX, PIPE AND VALVE
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
The Detectron Co., 5631 Cahuenga Blvd., North Hollywood, Calif.
Fischer Research Lab., Inc., 1961 University Ave, Palo Alto, Calif.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
The Goldak Co., 1544 W. Glenoaks Blvd., Glendale 1, Calif.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.
Wilkinson Products Co., 2987 Chevy Chase Drive, Pasadena 3, Calif.

LUBRICANTS, VALVE
American Car and Foundry Co., Valve Div., 1501 Ferry Avenue East, Detroit, Mich.

MANHOLE FRAMES, COVERS
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
R. D. Cole Mfg., Newnan, Ga.
The E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.

MANOMETERS
Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
Fischer & Porter Company, Dept. 9F, Hatboro, Pa.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Wallace and Tiernan, Newark 1, N. J.

MASONRY SAWS
(See Saws, Concrete & Masonry)

METER ACCESSORIES, BOXES, HOUSING SETTING, ETC.
Art Concrete Works, Pasadena, Calif.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., Oakaloosa, Iowa.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.

METER COUPLINGS & YOKES
Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Glauber Brass, Inc., Kinsman, Ohio.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., Decatur 70, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.
Worthington-Gamon Meter Division, Worthington Pump & Machinery Corp., 296 South St., Newark, N. J.

METER REPAIR PARTS
Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Hersey Mfg. Co., South Boston 27, Mass.
Meter Specialty Co., Sterick Bldg., Memphis, Tenn.
Neptune Meter Co., 50 West 50th St., New York 20, N. Y.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.

METERS, ELECTRIC
General Electric Co., Schenectady, N. Y.
Infilco Inc., 325 25th Pl., Chicago 16, Ill.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Simpson Electric Co., 5200 W. Kinzie St., Chicago 44, Ill.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

METERS, FLOW TUBE
Bethlehem Fdry. & Mach. Co., Bethlehem, Pa.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

METERS, GAS
Bailey Meter Company, 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Fischer & Porter Co., Hatboro, Pa.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.

METERS, HYDRAULIC TURBINES
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Worthington Pump and Machinery Corp., Harrison, N. J.

METER TESTING EQUIPMENT
Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Ford Meter Box Co., Wabash, Ind.
Hersey Mfg. Co., South Boston 27, Mass.
Neptune Meter Co., 50 W. 50th St., New York City.
Simpson Electric Co., 5200 W. Kinzie St., Chicago 44, Ill.
Worthington-Gamon Meter Co., Newark, N. J.

METERS, VENTURI
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 12, Ohio.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

METERS, WATER & SEWAGE
Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Buffalo Meter Co., 2909 Main St., Buffalo, N. Y.
Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Hersey Mfg. Co., South Boston 27, Mass.
Infilco, Inc., Tucson, Ariz.
Leupold & Stevens Instruments, Inc., 4445 N. E. Glisan St., Portland 13, Oregon.
Neptune Meter Co., 50 West 50th St., New York 20, N. Y.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.
Worthington-Gamon Meter Division, Worthington Pump & Machinery Corp., 296 South St., Newark, N. J.

METERS, CLEANING SOLUTION
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, O.
Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Neptune Meter Co., 50 West 50th Street, New York 20, New York.

MIXERS AND MIXING EQUIPMENT
(Chemical, Water and Sewage)
American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., Tucson, Ariz.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., 2413 W. Carson St., Pittsburgh 4, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equipment, Inc., Aurora, Ill.
Worthington Pump and Machinery Corp., Harrison, N. J.

MOTORS, ELECTRIC
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
General Electric Co., Schenectady, N. Y.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kansas.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

NIPPLES, PIPE
A. M. Byers Co., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Dresser Mfg. Co., Div., Bradford, Pa.
Glauber Brass, Inc., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kansas.

NO-OX-ID
Dearborn Chem. Co., 310 S. Michigan Ave., Chicago, Ill.

NOZZLES, FLOW
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

NOZZLES, SPRAY
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

OIL, CUTTING, THREADING
Ridge Tool Co., 400 Clark St., Elyria, Ohio.

OPERATING TABLES (Filter)
Amer. Water Softener Co., Philadelphia 33, Pa.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Infilco, Inc., Tucson, Ariz.
F. B. Leupold Co., Inc., 2413 W. Carson St., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

ORIFICES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

OZONE EQUIPMENT
The Welsbach Corp., Ozone Processes Div., 1500 Walnut St., Philadelphia 2, Pa.

PACKING
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Northrop & Co., Inc., Spring Valley, N. Y.

PAINT, ACID RESISTING
Atlas Mineral Prod. Co., Mertztown, Pa.
Barret Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Electro-Chemical Engr. & Mfg. Co., Broad & Grant Sts., Emmaus, Pa.
Haynes Products Co., 4007 Farnam St., Omaha 3, Nebr.
Inertol Co., Newark 5, N. J.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
U. S. Stoneware Co., Akron 9, Ohio.

PENSTOCKS
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.

Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, Warren, Pa.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Posey Iron Works, Inc., Lancaster, Pa.
Santa Fe Tank & Tower Co., 5401 S. Boyle Ave., Los Angeles 58, Calif.

pH TEST EQUIPMENT

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Beckman Instruments, Inc., 820 Mission St., So. Pasadena, Calif.
Coleman Instruments, Inc., 318 Madison St., Maywood, Ill.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Hellige, Inc., 37-18 Northern Blvd., Long Island City, N. Y.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
The Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan, Newark 1, N. J.

PHOTOELECTRIC COLORIMETERS

Beckman Instruments, Inc., 820 Mission St., South Pasadena, Calif.
Central Scientific Co., 1700 Irving Park Road, Chicago 13, Ill.
Hellige, Inc., 37-18 Northern Blvd., Long Island City, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond 5, Va.

PIPE & FITTINGS, SARAN, ETC.

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Carter Products Corp., Bedford, Ohio.
Sonken-Galamba Corp., 2nd and Riverview, Kansas City 18, Kan.

PIPE AND TANK COATINGS

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Dearborn Chem. Co., 310 S. Michigan Ave., Chicago, Ill.
Electro-Chemical Engr. & Mfg. Co., Broad & Grant Sts., Emmaus, Pa.
Johns-Manville Corp., 22 East 40th Street, New York 16, N. Y.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

PIPE, ASBESTOS-CEMENT

Johns-Manville Co., 22 E. 40th St., New York City.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Kensbey & Mattison Co., Ambler, Pa.

PIPE BENDING MACHINES (Hydraulic & Mechanical)

H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Greenlee Tool Co., 2136 12th St., Rockford, Ill.
Hays Mfg. Co., Erie, Pa.
Jos. G. Pollard Co., Inc., 141 S. Ashland Pl., Brooklyn 1, N. Y.

PIPE, CAST IRON

American Cast Iron Pipe Co., P. O. Box 2603, Birmingham 3, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Central Foundry Co., Murray and Pacific Sts., Newark, N. J.
James B. Clow & Sons, 201-299 No. Talman Ave., Chicago 12, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
McWane Cast Iron Pipe Co., P.O. Box 2601, Birmingham, Ala.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Southwestern Lumber Co., 7437 South Western Ave., Chicago 36, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.

PIPE, CEMENT LINED

American Cast ron Pipe Co., P. O. Box 2603, Birmingham 3, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Central Foundry Co., Murray and Pacific Sts., Newark, N. J.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Posey Iron Works, Inc., Lancaster, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

PIPE, CEMENT LINING OF

Centriline Corp., 140 Cedar St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
United States Pipe and Foundry Co., Burlington, N. J.

PIPE, CONCRETE, PRESSURE

Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

PIPE, COPPER, BRASS AND BRONZE

The American Brass Co., 25 Broadway, New York 4, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PIPE, CULVERT

Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, New York.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l. Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago, Ill.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 55 Liberty St., New York 5, N. Y.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.

PIPE CUTTING MACHINES

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
Jos. G. Pollard Co., Inc., New Hyde Park, N. Y.
Ridge Tool Co., 400 Clark St., Elyria, Ohio.
The A. P. Smith Mfg. Co., East Orange, N. J.
E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

PIPE DRILLS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Jos. G. Pollard Co., Inc., 141 Ashland Pl., Brooklyn 1, N. Y.
The A. P. Smith Mfg. Co., East Orange, N. J.

PIPE ENAMELS, PROTECTIVE—COAL TAR

Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Inertol Co., Newark 5, N. J.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.

PIPE FITTINGS (See Fittings)

PIPE, HARD RUBBER LINED

American Hard Rubber Co., 11 Mercer St., New York 13, N.Y.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.

PIPE JOINT COMPOUNDS

(See Jointing Compounds)

PIPE JOINTS (Mechanical)

Carson-Cadillac Corp., 1221 Pinson St., Birmingham, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Central Foundry Co., 386 Murray and Pacific Sts., Newark, N. J.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
United States Pipe and Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia 5, Pa.

PIPE JOINT PACKING, STERILE

Hydraulic Development Corp., 50 Church St., New York, N. Y.

PIPE JOINT TOOLS

Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.

PIPE LOCATORS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
The Detectron Co., 5631 Cahuenga Blvd., North Hollywood, Calif.
Fisher Research Lab., 1961 University Ave., Palo Alto, Calif.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Globe Phone Mfg. Corp., 2 Linden St., Reading, Mass.
The Goldak Co., 1544 W. Glenoaks Blvd., Glendale 1, Calif.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.
Wilkinson Products Co., 2967 Chevy Chase Drive, Pasadena 3, Calif.

PIPE, PLASTIC

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Carlon Products Corp., 10225 Meech Ave., Cleveland, Ohio.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
U. S. Stoneware Co., Akron 9, Ohio.
Yardley Plastics Co., 142 Parsons Ave., Columbus 15, O.

PIPE, PUSHERS (Hydraulic)

Greenlee Tool Co., 2136 12th St., Rockford, Ill.

PIPE, SEWER

Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Kensbey & Mattison Co., Ambler, Pa.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l. Clay Pipe Mfrs., 100 N. La Salle St., Chicago, Ill.
Preload Corp., 211 E. 37th St., New York 16, New York.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE, STEEL (All Types)

R. D. Cole Mfg. Co., Newnan, Ga.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Posey Iron Works, Inc., Lancaster, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PIPE TAPPING MACHINES

Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
The E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

PIPE TEST PLUGS

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 18, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Flexible Sewer Rod Equip. Co., 9069 Venice Blvd., Los Angeles, Calif.
Richmond Fdry. & Mfg. Co., P. O. Box 5150, Saunders Sta., Richmond, Va.
A. P. Smith Mfg. Co., E. Orange, N. J.

PIPE THAWING, ELECTRICAL, STEAM, FLAME

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.

PIPE TOOLS, (Asbestos, Cement)

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Kensbey & Mattison Co., Ambler, Pa.
Pilot Manufacturing Co., 420 Market St., San Francisco 11, Calif.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

PIPE TOOLS (Cutters, Extractors, Threaders, Wrenches, Etc.)

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Johns-Manville Corp., 22 East 40th Street, New York 16, N. Y.
Marlow Pumps, Ridgewood, N. J.
Pilot Manufacturing Co., 420 Market St., San Francisco 11, Calif.
Ridge Tool Co., 400 Clark St., Elyria, Ohio.
Trimont Mfg. Co., Div. of Aetna Industrial Corp., 55-71 Armory St., Roxbury 19, (Boston), Mass.

PIPE, VITRIFIED CLAY

(See Vitrified Clay Pipe and Products.)

PIPE WRAPPING

Johns-Manville Corp., 22 East 40th St., New York 16, N. Y.

PIPE, WROUGHT IRON

A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.
Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Posey Iron Works, Inc., Lancaster, Pa.
Sonken-Galamba, 2nd & Riverview, Kansas City 18, Kan.

PITOT TUBES

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Leupold & Stevens Inst., 4445 N. E. Glisson, Portland, Ore.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT

Dracco Corp., 4079 E. 116th St., Cleveland 5, Ohio.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

POROUS TUBES AND PLATES

Carborundum Co., Perth Amboy, N. J.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

POWER TAKE-OFFS
(Truck Type)

Davey Compressor Co., Kent, Ohio.
Payne Dean Co., Madison, Conn.

PRESTRESSED CONCRETE TANKS

Cement Gun Co., Inc., 1520 Walnut St., Allentown, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

PRESSURE REGULATORS

(See Regulators, Pressure)

PROPORTIONING EQUIPMENT

(See Chemical Feed and Proportioning Equip.)

PUMPING CONTROLS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Automatic Control Co., 1005 University Ave., St. Paul 4, Minn.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, O.
Barrett-Haentjens & Co., Hazleton, Pa.
Builders-Providence, Inc., 250 Harris Ave., Providence, R. I.
Chicago Pump Company, 2300 Wolfram St., Chicago 18, Ill.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
Foster Engineering Co., 835 Le-High Avenue, Union, N. J.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Lumenite Electronic Co., 407 S. Dearborn St., Chicago 5, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMP PRIMERS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Barrett-Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Marlow Pumps, Ridgewood, N. J.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Valve and Primer Corp., 127 N. Dearborn St., Chicago 2, Ill.

PUMPS, ACID-HANDLING

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Byron Jackson Co., P. O. Box 2017 Terminal Annex, Los Angeles 54, Calif.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Milton Roy Co., 1329 Mermaid Lane, Philadelphia 18, Pa.
Peerless Pump Div. Food Machinery and Chemical Corp., 301 W. Ave. 26, Los Angeles 31, Calif.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Worthing Pump & Mach. Corp., Harrison, N.J.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, CELLAR DRAINER

(See Pumps, Sump)

PUMPS, CENTRIFUGAL

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Barrett-Haentjens & Co., Hazleton, Pa.
Byron Jackson Co., P. O. Box 2017 Terminal Annex, Los Angeles 54, Calif.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee, Wis.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Domestic Engine & Pump Co., Shippensburg, Pa.
Economy Pumps, Inc., Div. of C. H. Wheeler Mfg. Co., 19th & Lehigh, Philadelphia 32, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Marlow Pumps, Ridgewood, N. J.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Worthington Pump and Machinery Corp., Harrison, New Jersey.
Yeoman Brothers Co., 1423 Dayton St., Chicago 22, Ill.

PUMPS, DEEP WELL

American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Byron Jackson Co., P. O. Box 2017 Terminal Annex, Los Angeles 54, Calif.
Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., Box 6818, Hollywood Sta., Memphis 8, Tenn.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Worthington Pump & Mach. Corp., Harison, N.J.

PUMPS, DIAPHRAGM

Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 12, Calif.
Domestic Engine & Pump Co., Shippensburg, Pa.
Dorr Co., Barry Place, Stamford, Conn.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Marlow Pumps, Inc., Ridgewood, N. J.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Yeomans Brothers Co., 1423 Dayton St., Chicago 22, Ill.

PUMPS, DRAINAGE (See Pumps, Sewage and Drainage)

PUMPS, HIGH PRESSURE FOR TRUCK MOUNTING

Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Marlow Pumps, Ridgewood, N. J.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, HYDRANT

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
A. Y. McDonald Mfg. Co., 12th and Pine Sts., Dubuque, Iowa.
Joseph G. Pollard Co., Inc., New Hyde Park, N. Y.

PUMPS, HYDRAULIC

De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Ross Valve Mfg. Co., Inc., 4 Oakwood Ave., Troy, N. Y.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, JETTING

Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Domestic Engine & Pump Co., Shippensburg, Pa.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Marlow Pumps, Ridgewood, N. J.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Iowa.

PUMPS, PORTABLE

Barrett, Haentjens & Co., Hazleton, Pa.
Byron Jackson Co., P. O. Box 2017 Terminal Annex, Los Angeles 54, Calif.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St. Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Deming Co., Salem, Ohio.
Domestic Engine & Pump Co., Shippensburgh, Pa.
Fairbanks Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Port Chester, N. Y.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Marlow Pumps, Ridgewood, N. J.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, ROTARY

Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, SELF PRIMING

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Ill.
W. S. Darley & Co., 2810 Washington Blv., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Domestic Engine & Pump Co., Shippensburgh, Pa.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Layne & Bowler, Inc., P. O. Box 215 Hollywood Sta., Memphis 8, Tenn.
Marlow Pumps, Ridgewood, N. J.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, SEWAGE AND DRAINAGE

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Domestic Engine & Pump Co., Shippensburgh, Pa.
Dorr Co., Barry Place, Stamford, Conn.
Economy Pumps, Inc., Div. of C. H. Wheeler Mfg. Co., 19th & Lehigh, Philadelphia 32, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corp., Port Chester, N. Y.
The Jaeger Machine Co., 550 W. Spring St., Columbus 16, Ohio.
Marlow Pumps, Ridgewood, N. J.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
S. Morgan Smith Co., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Worthington Pump and Machinery Corp., Harrison, New Jersey.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, SLUDGE

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Barrett-Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
DeLaval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Domestic Engine & Pumps Co., Shippensburgh, Pa.
Dorr Co., Barry Place, Stamford, Conn.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Marlow Pumps, Ridgewood, N. J.
Peerless Pump Div., Food Machinery & Chemical Corp., 301 W. Ave. 26, Los Angeles 31, Calif.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.

Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Worthington Pump and Machinery Corp., Harrison, New Jersey.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, SUMP (AND CELLAR DRAINER)

American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St, Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Byron Jackson Co., P. O. Box 2017 Terminal Annex, Los Angeles 54, Calif.
Ralph B. Carter Co., 192, Atlantic Street, Hackensack, N. J.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
W. S. Darley & Co., 2816 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Deming Co., Salem, Ohio.
Domestic Engine & Pump Co., Shippensburg, Pa.
Economy Pumps, Inc., Div. of C. H. Wheeler Mfg. Co., 19th & Lehigh, Philadelphia 32, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corporation, Port Chester, New York.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
A. Y. McDonald Mf., Co., 12th Pine Sts., Dubuque, Iowa.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Worthington Pump & Mach. Corp., Harrison, N. J.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, TURBINE

American Well Works, 100 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Byron Jackson Co., P. O. Box 2017 Terminal Annex, Los Angeles 54, Calif.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Deming Co., Salem, Ohio.
Economy Pumps, Inc., Div. of C. H. Wheeler Mfg. Co., 19th & Lehigh, Philadelphia 32, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., Box 6818, Hollywood Sta., Memphis 8, Tennessee.
Peerless Pump Dic., Food Machinery Corp., 301 West Avenue 26, Los Angeles 31, Calif.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Worthington Pump and Machinery Corp., Harrison, New Jersey.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS VACUUM

Allen-Billmyre Div., Lamson Corp., Syracuse 1, N. Y.
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Barrett, Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburgh, Pa.
Dracco Corp., 4070 E. 116th St., Cleveland 5, O.
Economy Pumps, Inc., Div. of C. H. Wheeler Mfg. Co., 19th & Lehigh, Philadelphia 32, P.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.
U. S. Hoffman Mach. Corp., 111 Fourth Ave., New York 3, N. Y.
Worthington Pump and Machinery Corp., Harrison, New Jersey.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

RAIN GAGES

Leupold & Stevens Instruments, Inc., 4445 N. E. Glisan, Portland 13, Oregon.
Lumenite Electronic Co., 407 S. Dearborn St., Chicago 5, Ill.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
M. C. Stewart, Ashburnham, Mass.

RATE OF FLOW CONTROLLERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Badger Meter Mfg. Co., 2371 North 30th St., Milwaukee, Wis.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Fischer & Porter Company, Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 783 Hampden Ave., St. Paul 4, Minnesota.
Infilco, Inc., Tuscon, Ari.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

RATE OF FLOW RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St. (P.O. Box 3084), Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisan, Portland, Ore.
Lumenite Electronic Co., 407 S. Dearborn St., Chicago 5, Ill.
Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
S. Morgan Smith Co., York, Pa.
Sparling Meter Co., Box 3277, Los Angeles 54, Calif.

REAMERS

Mueller Co., Decatur 70, Ill.
Ridge Tool Co., Elyria, Ohio.

RECARBONATORS

(See Carbonators)

REFRACTORIES

Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

REGULATORS, PRESSURE

(Water and Gas)

American Radiator Co., Bessemer Bldg., Pittsburg, Pa.
Automatic Control Co., 1005 University Ave., St. Paul, Minn.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Foster Engineering Co., 835 Le High Avenue, Union, N. J.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh.
Healy-Ruff Co., 783 Hampden Ave., St. Paul 4, Minnesota.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Mueller Co., Decatur 70, Ill.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
Rockwell Manufacturing Co., Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Ross Valve Mfg. Co., P. O. Box 596, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
The Williams Gauge Co., 1620 Penna Ave., Pittsburgh 32, Pa.

RESIDUAL CHLORINE CONTROL APPARATUS

Chemical Equipment Co., P. O. Box 3098, Term. Annex, Los Angeles 64, Calif.
Hellige, Inc., 37-18 Northern Blvd., Long Island City, N. Y.
LaMotte Chem. Co., Townson 4, Md.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace and Tiernan, Newark 1, New Jersey.

ROOF COATINGS

Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Haynes Products Co., 4007 Farnam St., Omaha 3, Nebr.
Johns-Manville Corp., 22 East 40th St., New York 16, New York.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.

RUBBER LINED PIPE AND VALVES

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Chem. Equip. Co., P. O. Box 3098 Term. Annex, Los Angeles 54, Calif.
Darling Valve & Mfg. Co., Williamsport, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
U. S. Stoneware Co., Akron 9, Ohio.

RUBBER PACKING GASKETS

Hamilton Kent Mfg. Co., Kent, Ohio.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Johns-Manville Corp., 22 East 40th St., New York 16, New York.
Northrop & Co., Spring Valley, N. Y.

RUST PREVENTION

(Tanks, Pipe Lines, Submerged Metal)

Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Calgon, Inc., Hagan Bldg., 323 4th Ave., Pittsburgh, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Electro Rust-Proofing Corp., (N. J.), Belleville, N. J.
Dearborn Chem. Co., 310 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Philadelphia Quartz Co., 1148 Public Ledger Bldg., Philadelphia 6, Pa.
U. S. Stoneware Co., Akron 9, Ohio.

SADDLES, PIPE

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Brandford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

SAMPLERS AND SAMPLING TABLES

Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Hardinge Co., Inc., 240 Arch St., York, Pa.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh, Pa.
Infilco, Inc., Tuscon, Ariz.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

SAW BLADES (Concrete & Masonry)

Clipper Manufacturing Co., 2800 Warwick Blvd., Kansas City 8, Mo.

SAWS, CONCRETE & MASONRY

Clipper Manufacturing Co., 2800 Warwick Blvd., Kansas City 8, Mo.

SAND EXPANSION INDICATORS

Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
Infilco, Inc., Tuscon, Ariz.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

SCALES, SLUDGE CONVEYOR

Builders-Providence., Inc.,350 Harris Ave., Providence 1, R. I.
Fairbanks, Morse & Co., 600 South Michigan Ave., Chicago 5, Ill.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.

SCALES, WEIGHING

Fairbanks-Morse Co., 600 S. Michigan Ave., Chicago 5, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Nichols Engineering & Research Corp., 70 Pine St., New York 5, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Wallace & Tiernan, Belleville 9, N. J.

SCREENINGS, DEWATERERS

Gen. Amer. Trans. Corp., 10 E. 49th St., New York 17, N. Y.

SCREENINGS GRINDERS

(See Grinders)

SCREENS, INTAKE

Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

SCREENS, SEWAGE

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 2084), Seattle, Wash.
Infilco, Inc., Tuscon, Ariz.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Walker Process Equip. Co., Aurora, Ill.

SCREENS, VIBRATING

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Syntron Co., 650 Lexington, Homer City, Pa.

SCREEN, WATER WELL

Layne & Bowler, Inc., Box 6818, Hollywood Sta., Memphis 8, Tennessee.

SCUM REMOVERS

(See Clarifiers.)

SEGMENT BLOCKS AND PIPE LINER PLATES (Vitrified)
Infilco, Inc., Tucson, Ariz.
Nat'l Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago 2, Ill.

SEPTIC TANK CLEANERS
Ace Pipe Cleaning Contractors, Inc., 2003 Indiana Ave., Kansas City 1, Mo.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Rootes Motors, Inc., 27-11 Bridge Plaza Rd., Long Island City, N. Y.

SEPTIC TANKS (Vitrified Clay)
Nat'l Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago 2, Ill.

SERVICE BOXES
Central Foundry Co., Murray & Pacific Sts., Newark, N. J.
James B. Clow & Sons., 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
A. Y. McDonald Mfg. Co., 12th Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

SERVICE PIPE
The American Brass Co., 25 Broadway, New York 4, New York.
Glauber Brass, Inc., Kinsman, Ohio.
Johns-Manville Corp., 22 East 40th Street, New York 16, N. Y.

SEWAGE EJECTORS
(See Ejectors, Pneumatic.)

SEWAGE SAMPLERS
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Phipps & Bird, Inc., 308 S. 6th St., Richmond 5, Va.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

SEWAGE SLUDGE DRYERS
(See Drying Systems, Sludge)

SEWAGE SLUDGE INCINERATOR
(See Incinerators)

SEWAGE TREATMENT PROCESSES
The Bio-Chemical Process, 2266 N. Meridian St., Indianapolis, Ind.
Infilco, Inc., Tucson, Ariz.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
R. R. Carter Sales Inc., 192 Atlantic St., Hackensack, N. J.

SEWER CLEANING EQUIP. AND SERVICE
Ace Pipe Cleaning Contractors, Inc., 2003 Indiana Ave., Kansas City 1, Mo.
Bucyrus-Erie Co., South Milwaukee, Wis.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Expanding Sewer Machine Co., 108 E. Walnut St., Nappanee, Ind.
J. C. Fitzgerald, P. O. Box 239, Coral Gables 34, Fla.
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Phelps Dodge Refining Corp., 40 Wall St., New York 5, N. Y.
Pittsburgh Pipe Cleaner Co., 133 Dahlem St., Pittsburgh 6, Pa.
Rootes Motors, Inc., 27-11 Bridge Plaza Rd., Long Island City, N. Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SEWER PIPE
(See Pipe, Sewer.)

SEWER PIPE JOINTS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hamilton Kent Mfg. Co., Kent, Ohio.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Hydraulic Development Corp., 50 Church St., New York City.
National Clay Pipe Manufacturers, Inc., 100 North LaSalle St., Chicago 2, Illinois.
Northrop & Company, Inc., Spring Valley, N. Y.
L. A. Weston Co., 2 Dean St., (P. O. Box 6), Adams, Mass.

SEWER RODS
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Expanding Sewer Machine Co., 108 E. Walnut St., Nappanee, Ind.
Flexible Sewer-Rod Eqpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
Joseph G. Pollards Co., Inc., New Hyde Park, N. Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SIPHONS (Sewage)
American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
H. D. Fowler Co., Inc., 901 Lane St., (P. O. Box 3084), Seattle, Wash.
Infilco, Inc., Tucson, Ariz.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Rootes Motors, Inc., 27-11 Bridge Plaza Rd., Long Island City, N. Y.

SLEEVES, PIPE REPAIR
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
Mueller Co., 2501 Chestnut St., Chattanooga, Tenn.
Rensselaer Valve Co., Ontario Street, Troy, New York.
A. P. Smith Mfg. Co., East Orange, N. J.
Warren Foundry & Pipe Corp., 55 Liberty Street, New York 5, N. Y.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

SLEEVES, TAPPING (Valve)
Eddy Valve Co., Waterford, N. Y.
Darling Valve & Manufacturing Co., Williamsport, Penna.
Dresser Manufacturing Div., 69 Fisher Ave., Bradford, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Mueller Co., Decatur 70, Ill.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Rensselaer Valve Co., Ontario Street, Troy, New York.
A. P. Smith Mfg. Co., East Orange, N. J.

SLUDGE COLLECTORS
American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Infilco, Inc., Tucson, Ariz.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

SLUDGE DISINTEGRATORS
Infilco, Inc., Tucson, Ariz.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE EJECTORS
(See Ejectors, Pneumatic.)

SLUDGE ELEVATORS, LIQUID
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Hardinge Corp., York, Pa.
Jeffrey Mfg. Co., 966 N. 4th St., Columbus 16, O.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equip., Inc., Aurora, Ill.

SLUDGE GAS ENGINES
(See Engines, Sludge Gas)

SLUDGE PUMPS
(See Pumps, Sludge)

SLUDGE SAMPLERS
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chicago Pump Co., 2349 Wolfram St., Chicago 18, Ill.
Infilco, Inc., Tucson, Ariz.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

SNUBBERS
(See Silencers.)

SODA ASH
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Diamond Alkali Co., 300 Union Commerce Bldg., Cleveland 14, Ohio.
Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Maryland.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.
Pittsburgh Plate Glass Co., Columbia Chemical Div., Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
Solvay Sales Div., Allied Chemical & Dye Corporation, 40 Rector Street, New York 6, New York.

SODIUM BISULPHITE
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

SODIUM CHLORITE
Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Maryland.
Phipps & Bird, Inc., 303 S. Sixth St., Richmond, Va.

SODIUM PHOSPHATES (Glassy)
Blockson Chemical Co., P. O. Box 1407, Joliet, Illinois.
Calgon, Inc., Hagan Bldg., 323 Fourth Ave., Pittsburgh 30, Pa.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.

SODIUM SILICATE
Diamond Alkali Co., 300 Union Commerce Bldg., Cleveland 14, Ohio.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Philadelphia Quartz Co., 1146 Public Ledger Bldg., Philadelphia 6, Pa.

SOFTENERS
(See Water Softening Equipment)

SPEED REDUCERS, TRANSMISSION
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Worthington Pump and Machinery Corp., Harrison, N. J.

SPRINKLING FILTER EQUIP.
American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter, 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Infilco, Inc., Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

SPRINKLING FILTER UNDERDRAINS
(See Filter Underdrains, Sewage.)

STACKS
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, Warren, Pa.
Posey Iron Works, Inc., Lancaster, Pa.

STANDPIPES
(See Tanks and Standpipes.)

STANDPIPE AND TANK PRESERVATION
(See Cathodic Protection Process.)

STERILIZING WATER MAINS
(See Water Main Sterilization)

STIRRERS (Laboratory)
Omega Machine Co., 345 Harris Avenue, Providence 1, Rhode Island.
Phipps & Bird, Inc., 303 S. 6th St., Richmond, Va.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

STOKERS
Combustion Engineering-Superheater, Inc., 200 Madison Ave., New York, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Link-Belt Co., 2410 W. 18th St., Chicago 8, Ill.
Westinghouse Electric & Mfg. Co., Pittsburgh 30, Pa.

STORAGE TANKS
(See Standpipes and Tanks)

STRAINERS, SUCTION
Barrett, Haentjens & Co., Hazleton, Pa.
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
R.-S. Products Corp., 4600 Germantown Ave., Philadelphia, Pa.

SULPHATE OF ALUMINA
(See Filter Alum)

SULPHUR DIOXIDE (Liquid)
Tennessee Corp., 1028 Connecticut Ave., N.W., 823-A, Washington, D. C.

SUPERNATANT LIQUOR (Handling and Treatment)
Chicago Pump Co., 2300 Wolfram Street, Chicago 18, Illinois.

Pacific Flush Tank Co., 4141 Ravenswood Ave., Chicago 13, Ill.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

SWITCHBOARD & SWITCH GEAR

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Mfg. Co., Pittsburgh 30, Pa.

TANK MAINTENANCE & REPAIR

Cement Gun Co., Inc., 1520 Walnut Street, Allentown, Penna.
Dixie Tank & Bridge Co., P. O. Box 14, Memphis 1, Tenn.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, 630 Fifth Ave., New York, N. Y.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Specimon Elevated Tank Service, 822 N. Court St., Rockford, Ill.

TANKS & PIPES, WOOD

Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Santa Fe Tank & Tower Co., 5401 S. Boyle Ave., Los Angeles 58, Calif.

TANKS AND STANDPIPES, ELEVATED (Steel)

Amer. Car and Foundry Co., 30 Church St., New York 8, N. Y.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, Warren, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
General American Process Equipment Div., 420 Lexington Ave., New York 17, N. Y.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Posey Iron Works, Inc., Lancaster, Pa.
Santa Fe Tank & Tower Co., 5401 S. Boyle Ave., Los Angeles 58, Calif.
Senken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
U. S. Stoneware Co., Akron 9, Ohio.

TANKS, RUBBER LINED

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Atlas Mineral Products Co., Mertztown, Pa.
R. D. Cole Mfg. Co., Newnan, Ga.
Electro-Chemical Engr. & Mfg. Co., Broad & Grant Sts., Emmaus, Pa.
Hammond Iron Works, Warren, Pa.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Posey Iron Works, Inc., Lancaster, Pa.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
U. S. Stoneware Co., Akron 9, Ohio.

TAPPING MACHINES

Glauber Brass, Inc., Kinsman, Ohio.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., East Orange, N. J.
S. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

TASTE & ODOR REMOVAL CHEMICALS

Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York 17, N. Y.
Mathieson Chem. Corp., 60 E. 42nd St., New York 17, N. Y.
Phelps Dodge Refg. Corp., 40 Wall St., New York, N. Y.
Welsbach Corp., Ozone Processes Division, 1500 Walnut Street, Philadelphia 2, Pa.

TESTERS (Water Meter)

Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hersey Mfg. Co., South Boston 27, Mass.
Neptune Meter Co., 50 W. 50th St., New York City.
Worthington-Gamon Meter Co., Newark, N. J.

TEST PLUGS (for Pipe)

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Eddy Valve Co., Waterford, N. Y.
Flexible Sewer Rod Equip. Co., 9959 Venice Blvd., Los Angeles, Calif.
Glauber Brass, Inc., Kinsman, Ohio.
Richmond Fdry. & Mfg. Co., P. O. Box 5150, Saunders Sta., Richmond, Va.
A. P. Smith Mfg. Co., E. Orange, N. J.

THICKENERS (Sludge)

Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Dorr Co., Barry Place, Stamford, Conn.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., Tucson, Ariz.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Walker Process Equip., Inc., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

TOOL BOXES, PORTABLE

Littleford Bros., Inc., 453 E. Pearl St., Cincinnati 21, Ohio.

TOOLS, PIPE

(See Pipe Tools)

TOOLS, PNEUMATIC

Jaeger Machine Co., 716 Dublin Ave., Columbus, Ohio.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.

TRACTORS, BULLDOZERS, Etc.

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Bucyrus-Erie Co., South Milwaukee, Wis.

TRANSFORMERS, ELECTRIC

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Corp., Pittsburgh, Pa.

TRAPS, DRIP, FLAME, SEDIMENT, STEAM

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084), Seattle, Wash.
Infilco, Inc., Tucson, Ariz.
Josam Mfg. Co., 1302 Ontario St., Cleveland 13, Ohio.
Neptune Meter Co., 50 W. 50th St., New York 20, N. Y.
Pacific Flush Tank Co., 4341 Ravenswood Ave., Chicago 13, Ill.
The Williams Gauge Co., 1620 Pennsylvania Ave., Pittsburgh 33, Pa.

TRENCHING EQUIPMENT

Bucyrus-Erie Co., South Milwaukee, Wis.
Hydrauger Corp., Ltd., 116 New Montgomery St., San Francisco, Calif.

TRICKLING FILTER EQUIPMENT

American Well Wks., 109 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic Street, Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Infilco, Inc., Tucson, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Avenue, Chicago 13, Illinois.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Walker Process Equipment, Inc., Aurora, Ill.
Yeomans Bros., 1423 N. Dayton St., Chicago 22, Ill.

TRICKLING FILTER UNDERDRAINS

(See Filter Underdrains)

TRITURATORS

(See also Grinders)

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.

TUNNEL LINER PLATES

Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.

TURBIDIMETERS

Heilige, Inc., 37-18 Northern Blvd., Long Island City 1, N. Y.
Klett Mfg. Co., 179 E. 87th St., New York 28, N. Y.
Phippe & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

TURBINES, HYDRAULIC

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

TURBINES, STEAM

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Nottingham Way, Trenton 2, N. J.
Westinghouse Elect. Corp., Pittsburg 30, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

UNIT SUBSTATIONS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

VACUUM FILTERS

Process Engineers, Inc., 821 Market St., San Francisco, Calif.
U. S. Hoffman Machinery Corp., 111 Fourth Ave., New York 3, N. Y.
U. S. Stoneware Co., Akron 9, Ohio.

VALVE BOXES

Central Foundry Co., Murray & Pacific Sts., Newark, N. J.
Chapman Valve Mfg., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Ford Meter Box Co., Wabash, Ind.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
H. W. Clark Co., Mattoon, Ill.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., Decatur 70, Ill.
A. P. Smith Mfg. Co., E. Orange, N. J.
Veraks Products, Inc., Grand Ave. & Skokie Rd., Waukegan, Wis.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.

VALVE BOX LOCATORS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
The Detectron Co., 5631 Cahuenga Blvd., North Hollywood, Calif.
Globe Phone Mfg. Co., 2 Linden St., Reading, Mass.
The Goldak Co., 1544 Glenoaks Blvd., Glendale 1, Calif.

VALVE INSERTING MACHINES

A. P. Smith Mfg. Co., E. Orange, N. J.

VALVE OPERATOR

(See Gate Valve Operator)

VALVES, AIR RELEASE (See Air Release Valves)

VALVES, AIR RELEASE & VACUUM BREAKING

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N.Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Norwalk Valve Co., 33 Railroad Avenue, South Norwalk, Conn.
Rockwell Mfg. Co., Nordstrom Valve Div., 400 W. Lexington Ave., Pittsburgh 8, Pa.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Simplex Valve & Meter Co., 6742 Upland St., Philadelphia 42, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Valve and Primer Corp., 127 N. Dearborn St., Chicago, Ill.
Williams Gauge Co., 1620 Pennsylvania Ave., Pittsburgh 33, Pa.

VALVES, ALTITUDE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Foster Engineering Co., 835 Le-High Avenue, Union, N. J.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 207 Keenan Bldg., Pittsburgh 22, Pa.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, BACKWATER

The Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Co., Keenan Bldg., Pittsburgh 22, Pa.
Hersey Mfg. Co., South Boston 27, Mass.
The Kennedy Valve Mfg. Co., 1036 E. Water St., Elmira, N. Y.
Ross Valve Mfg. Co., Inc., 4 Oakwood Ave., Troy, N. Y.

VALVES, BUTTERFLY

Crane Co., 836 S. Mich. Ave., Chicago 5, Ill.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P.O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Decatur 70, Ill.
Pelton Water Wheel Co., 2929 19th St., San Francisco, Calif.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, CHECK

Amer. Car and Foundry Co., 30 Church St., New York 8, N. Y.
Barrett Haentjens & Co., Hazleton, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Foster Engineering Co., 835 Le-High Avenue, Union, N. J.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Golden-Anderson Valve Specialty Co., 207 Keenan Bldg., Pittsburgh 22, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hersey Mfg. Co., South Boston 27, Mass.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Jeffrey Mfg. Co., 996 N. 4th St., Columbus 46, Ohio.
The Kennedy Valve Mfg. Co., 1036 E. Water St., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
Rensselaer Valve Co., Ontario Street, Troy, New York.
A. P. Smith Mfg. Co., E. Orange, N. J.
S. Morgan Smith Co., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kansas.
Williams Gauge Co., 1620 Penn Ave., Pittsburgh 12, Pa.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, CHLORINE

Amer. Car and Fdy. Co., 30 Church St., New York 8, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Wallace and Tiernan, Newark 1, New Jersey.

VALVES, COMPRESSION

Glauber Brass, Inc., Kinsman, Ohio.

VALVES, CONE

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
S. Morgan Smith Co., York, Pa.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.

VALVES, DIAPHRAGM

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Fischer & Porter Co., Hatboro, Pa.
Foster Engineering Company, 835 LeHigh Avenue, Union, New Jersey.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Grinnell Co., Inc., 240 W. Exchange St., Providence 1, R. I.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Infilco, Inc., Tuscon, Ariz.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

VALVES, ELECTRICALLY OPERATED

(See Valves, Motor Operated.)

VALVES, EMERGENCY TRIP

Golden-Anderson Valve Spec. Co., 207 Keenan Building, Pittsburgh 22, Pa.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.

VALVES, FLAP

Chapman Valve Mfg. Co., Indian Orchard, Mass.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., Decatur 70, Ill.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

VALVES, FLOAT

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Foster Engineering Co., 835 Le-High Avenue, Union, New Jersey.
Golden-Anderson Valve Specialty Co., 207 Keenan Building, Pittsburgh 22, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th & Pine St., Dubuque, Iowa.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, FOOT

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Eddy Valve Co., Waterford, N. Y.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th & Pine St., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
The Williams Gauge Co., 1620 Penn. Ave., Pittsburgh 12, Pa.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, FOUR WAY

American Water Softener Co., Philadelphia 33, Pa.
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
The Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tuscon, Ariz.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2412 W. Carson St., Pittsburgh 4, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Rockwell Manufacturing Co., Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
The E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

VALVES, GATE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., 1036 E. Water St., Elmira, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th & Pine St., Dubuque, Iowa.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., Decatur 70, Ill.
Rensselaer Valve Co., Ontario Street, Troy, New York.
A. P. Smith Mfg. Co., E. Orange, N. J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
R. D. Wood Co., 1072 Public Ledger Bldg., Philadelphia, Pa.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

VALVES, HARD RUBBER LINED

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Manufacturing Co., Williamsport, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Infilco, Inc., Tuscon, Ariz.
R-S Products Corp., 4600 Germantown Ave., Philadelphia, Pa.

VALVES, HYDRAULIC CYLINDER OPERATED

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 207 Keenan Building, Pittsburgh 22, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., 1036 E. Water St., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., Decatur 70, Ill.
Rensselaer Valve Company, Ontario Street, Troy, New York.
Rockwell Manufacturing Co., Nordstrom Valve Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
A. P. Smith Mfg. Co., East Orange, N. J.
S. Morgan Smith Co., York, Pa.

VALVES, LUBRICATED PLUG

American Car and Foundry Co., Valve Division, 1501 Ferry Avenue East, Detroit, Michigan.
Rockwell Manufacturing Co., Nordstrom Valve Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

VALVES MECHANICAL JOINT

Eddy Valve Co., Waterford, N. Y.

VALVES, MOTOR OPERATED

Chapman Valve Mfg. Co., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
H. D. Fowler Co. Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 207 Keenan Building, Pittsburgh 22, Pa.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., 1036 E. Water St., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Mueller Co., Decatur 70, Ill.
Payne Dean and Co., Madison, Conn.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Rockwell Manufacturing Co., Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
A. P. Smith Mfg. Co., East Orange, N. J.
S. Morgan Smith Co., York, Pa.

VALVES, MUD AND PLUG

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
The Filer & Stowell Co., 147 E. Becher Street, Milwaukee 7, Wisconsin.
Infilco, Inc., Tuscon, Ariz.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., Decatur 70, Ill.
Roberts Filter Mfg. Co., Darby, Pa.

VALVES, PRESSURE REDUCING

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Foster Engineering Co., 835 Le-High Avenue, Union, New Jersey.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 207 Keenan Building, Pittsburgh 22, Pa.
Lee Hydraulic Co., P. O. Box 804, Troy, N. Y.
Mueller Co., Decatur 70, Ill.
Norwalk Valve Co., 33 Railroad Avenue, South Norwalk, Conn.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith, York, Pa.

VALVES, RELIEF

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Foster Engineering Co., 835 Le-High Avenue, Union, New Jersey.

Golden-Anderson Valve Specialty Co., 207 Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Iowa.
Mueller Co., Decatur 70, Ill.
Neptune Meter Co., 50 West 50th St., N. Y. 20.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
S. Morgan Smith Co., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kansas.
The Welsbach Corp., Kitson Division, 1500 Walnut Street, Philadelphia 2, Pa.

VALVES, RUBBER, GLASS AND LEAD LINED

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Darling Valve & Mfg. Co., Williamsport, Penna.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Infilco, Inc., Tucson, Ariz.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith, York, Pa.
U. S. Stoneware Co., Akron 9, Ohio.

VALVES, SPECIAL, AUTOMATIC (Including Remote Control.)

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Barrett, Haentjens & Co., Hazleton, Pa.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
Foster Engineering Co., 835 Le-High Avenue, Union, New Jersey.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Specialty Co., 207 Keenan Bldg., Pittsburgh 22, Pa.
Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.
Infilco, Inc., Tucson, Ariz.
Iowa Valve Co., 201-299 N. Talman Ave., Chicago 80, Ill.
The Kennedy Valve Mfg. Co., 1936 E. Water St., Elmira, N. Y.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Rensselaer Valve Co., Ontario Street, Troy, New York.
Rockwell Manufacturing Co., Nordstrom Valve Division, 400 N. Lexington Ave., Pittsburgh 8, Pa.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.
A. P. Smith Mfg. Co., 595 N. Arlington Ave., E. Orange, N. J.

VALVES, WATER METER SPECIAL

Ford Meter Box Co., Wabash, Ind.
Hersey Mfg. Co., South Boston 27, Mass.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.

VARIABLE SPEED TRANSMISSIONS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Worthington Pump and Machinery Corp., Harrison, N. J.

VENTURI TUBES

American Water Softener Co., Philadelphia 33, Pa.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

VIBRATING SCREENS (Liquid)

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

VISES, PIPE

H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
The Ridge Tool Co., 400 Clark Street, Elyria, Ohio.
Trimont Mfg. Co., Div. of Aetna Industrial Corp., 55-71 Armory St., Roxbury 19, (Boston), Mass.

VITRIFIED CLAY PIPE AND PRODUCTS

Nat'l. Clay Pipe Mfrs., Inc., 100 N. La Salle St., Chicago 2, Ill.
U. S. Stoneware Co., Akron 9, Ohio.

WASTE GAS BURNERS

H. D. Fowler Co., Inc., 901 Lane St. (P. O. Box 3084), Seattle, Wash.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

WATER ANALYSIS EQUIPMENT AND REAGENTS

(See Laboratory Apparatus and Reagents)

WATER HAMMER ARRESTERS

H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Pelton Water Wheel Co., 18th and Alabama Sts., San Francisco 10, Calif.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.

WATER LEAK, LOCATING INSTRUMENTS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
The Detectron Co., 5631 Cahuenga Blvd., North Hollywood, Calif.
Fisher Research Lab. Inc., 1961 University Ave., Palo Alto, Calif.
H. D. Fowler Co. Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Globe Phone Mfg. Corp., 2 Linden St., Reading, Mass.
The Goldak Co., 1544 W. Glenoaks Blvd., Glendale 1, Calif.
Joseph H. Pollard Co., Inc., New Hyde Park, N. Y.
Wilkinson Products Co., 3987 Chevy Chase Drive, Pasadena 3, Calif.

WATER LEVEL CONTROL

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Automatic Control Corp., 1005 University Ave., St. Paul 4, Minn.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
Foster Engineering Co., 835 Le-High Avenue, Union, New Jersey.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Infilco, Inc., Tucson, Ariz.
Lumenite Electronic Co., 407 S. Dearborn St., Chicago 5, Ill.
Leupold & Stevens Instruments, Inc., 4445 N. E. Glisan, Portland 13, Oregon.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Ross Valve Mfg. Co., 4 Oakwood Ave., Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

WATER LEVEL RECORDERS

Automatic Control Co., 1005 University Ave., St. Paul 4, Minn.
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders-Providence, Inc., 350 Harris Ave., Providence 1, R. I.
Fisher Research Laboratory, Inc., 1961 University Ave., Palo Alto, Calif.
Fischer & Porter Co., Dept. 9F, Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., Tucson, Ariz.
Leupold & Stevens Instruments, Inc., 4445 N. E. Glisan St., Portland 13, Oregon.
Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

WATER MAIN CLEANING

Ace Pipe Cleaning Contractors, Inc., 2003 Indiana Ave., Kansas City 1, Mo.
Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 50 Church St., New York 7, N. Y.
Pittsburgh Pipe Cleaner Co., 133 Dahlem St., Pittsburgh 6, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

WATER MAIN PACKING GASKETS

Johns-Manville Corp., 22 East 40th Street, New York 16, New York.
Northrop & Co., Spring Valley, N. Y.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS

Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
Haynes Products Co., 4007 Farnam St., Omaha 3, Neb.
Inertol Co., Newark 5, N. Y.
Johns-Manville, 22 E. 40th St., New York City.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Stuart Corp., 516 N. Charles St., Baltimore, Md.

WATER SOFTENING CHEMICALS AND COMPOUNDS

(See Individual Chemicals for Water Purification and Softening)

WATER SOFTENING EQUIPMENT

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 100 N. Broadway, Aurora, Ill.
Blockson Chemical Co., P. O. Box 1407, Joliet, Illinois.
Builders-Providence, Inc., 350 Harris Ave., Providence, R. I.
R. B. Carter, 192 Atlantic Ave., Hackensack, N.J.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Dorr Co., Inc., Barry Place, Stamford, Conn.
Infilco, Inc., Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Maryland.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco, Calif.
Roberts Filter Mfg. Co., Darby, Pa.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Worthington Pump and Machinery Corp., Harrison, New Jersey.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER SUPPLY CONTRACTORS

(See Contractors)

WATER TREATMENT FOR SCALE AND CORROSION

Amer. Water Softener Co., Philadelphia 33, Pa.
Calgon, Inc., 323 4th Ave., Hagan Bldg., Pittsburgh 30, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
General Chemical Div., Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Worthington Pump & Mach. Corp., Harrison, N. J.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER TREATMENT PLANTS (Steel)

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
The Dorr Company, Barry Place, Stamford, Conn.
Infilco, Inc., Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Worthington Pump & Mach. Corp., Harrison, N. J.

WEED KILLERS

Barrett Div., Allied Chemical & Dye Corp., 40 Rector St., New York 6, N. Y.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Dow Chemical Co., Midland, Mich.
General Chemical Division, Allied Chemical & Dye Corp., 40 Rector Street, New York 6, N. Y.
Koppers Company, Inc., Koppers Bldg., Pittsburgh 19, Pa.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Phelps Dodge Refining Corp., 40 Wall St., New York 5, N. Y.

WELLS, COMPLETE

Layne & Bowler, Inc., Box 6818 Hollywood Sta., Memphis 8, Tennessee.

WRAPPING, PIPE

(See Pipe, Wrapping)

WRENCHES, REVERSIBLE RATCHET

Dresser Mfg. Co., 251 Fisher Ave., Bradford, Pa.
Eddy Valve Co., Waterford, N. Y.

WROUGHT IRON (Pipe, Gates, Bars, Etc.)

A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.
Posey Iron Works, Inc., Lancaster, Pa.

ZEOLITE AND ZEOLITE SOFTENERS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Amer. Water Softener Co., Philadelphia 33, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.
Infilco, Inc., Tucson, Ariz.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Layne-Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

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Newark 1, New Jersey

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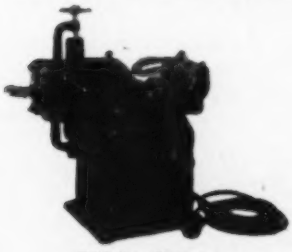
Recent developments in water works practice show that bacteria practically cease to exist where Free Residual Chlorination, as accomplished by the Break-Point Process, is employed. Such chlorination assures the production of free available chlorine residuals which have a high killing potential. In many plants bacterial control by the Break-Point Process has been augmented with additional benefits such as improved coagulation, increased color removal, elimination of algal conditions, reduced chemical costs and increased length of filter runs with a resultant saving in wash water.

TYPE MASV AUTOMATIC SOLUTION FEED VISIBLE VACUUM CHLORINATOR

Where unusual or extreme fluctuations in water or sewage flow are encountered, the Type MASV meets the chlorination requirements. It embodies all the advantages of automatic proportioning of chlorine feed, and automatic starting and stopping with the outstanding features of the Visible Vacuum Control Chlorinator — rugged construction, simplicity of operation and low maintenance costs.

Type MASV Automatic Visible Vacuum Chlorinator

THE W&T HYPOCHLORINATOR



W&T Hypochlorinator

Chlorination of small water supplies involves problems which the W&T Hypochlorinator is especially designed to meet. This equipment feeds either calcium or sodium hypochlorite in solution form and is furnished in three types.

The Electrically Operated type is particularly useful for small pumped water supplies. Since water pressure furnishes the major part of the operating power, the cost of electricity is but a few cents a day. Automatic Water Operated Hypochlorinators automatically proportion the chlorine solution to the flow of water and are especially adapted to small gravity water supplies with wide variations in flow.

The Belt Driven unit is a sturdy, dependable unit for use where electric power is not available or where operation is to be synchronized with pumping equipment driven by gasoline engine or other similar motive power.

TYPE MDPA DIRECT FEED AMMONIATOR

A self-contained unit specially adapted to handling ammonia gas, embodying the same sound principles of design and construction exemplified in W&T Chlorinators. Rugged, accurate and dependable.

Type MDPA Ammoniator

DRY CHEMICAL FEEDERS

For the application of dry chemicals, Wallace & Tiernan offers a complete line of feeding equipment. The Types MO, MOF and MOI Dry Feeders include such advantages as positive agitation, easy calibration and accurate feed over ranges of from 0.5 to 200 pounds per hour, depending upon the chemical used.

CONVENIENCE

W&T is represented in each of the 39 cities by a service staff prepared to give advice on the proper equipment for any chlorination problem.

Current literature on the many phases of chlorination, ammoniation and dry chemical feeding is available on request.

WATER AND SEWAGE WORKS INFORMATION

Where to Find It

LINN H. ENSLOW
Editor
"Water & Sewage Works"

LIST NO. 1—FOR WATER WORKS MANAGERS AND OPERATORS

[For Small and Moderate Size Systems.]

Books	*Publishers*	*Authors*
American Civil Engineering Handbook—5th Ed. ($9.00)	John Wiley & Sons, New York City	Merriman & Wiggin
Bul. No. 21 (a Handbook on Hydraulics) (F)	National Tube Co., Pittsburgh, Pa.	
Census of Water Treatment Plants	A.W.W.A.	
Chlorine Manual (F)	The Chlorine Institute, New York 17, N.Y.	
Conversion Factors for Engineers (F)	The Dorr Co., New York City	
Copper Sulfate in Control of Micro Organisms (F)	Phelps Dodge Refining Corp., New York City	Hale
Elements of Water Supply Engineering (2nd Ed.) ($4.00)	John Wiley & Sons, New York City	Waterman
Engineering Data in Flow of Fluids in Pipes (F)	Crane Co., Chicago	
Fire Engine Tests and Fire Stream Tables (F)	National Board of Fire Underwriters, N. Y. C.	
Handbook of Fire Protection ($4.50)	D. Van Nostrand Co., New York City	Crosby, Fiske & Forster
Hydraulic Tables—3rd Ed. ($2.50)	John Wiley & Sons, New York City	Williams & Hazen
Lab. Manual—Water and Sewage Anal., 3rd Ed. ($3.00)	McGraw-Hill Co., New York City	Theroux, Eldridge, Mallman
Lefax—Data Sheets for Loose Leaf Note Books	Lefax, Inc., Philadelphia, Pa.	Various
Manual for Water Plant Operators ($6.50)	Chemical Publishing Co., Brooklyn 2, N. Y., c/o State Dept. H.	A. A. Hirsch
Manual for Water Works Operators ($3.00)	Texas Water and Sewage Works Assn., Austin, Tex.	Various
Manual of Recommended Water Sanitation Practice (15c)	U.S. Govt. Printing Office, Washington, D.C.	
Manuals and Specifications of A.W.W.A.	Amer. Water Works Assn., New York City	
Manual of Water Quality and Treatment (2nd Ed.)		
Manual of Water Works Accounting ($4.00)		
Procedure for Disinfecting Water Mains ($0.15)		
Recommended Practice for Distribution System Records (2nd Ed.) ($0.45)		
Recommended Practice for Repairing and Repainting Elevated Tanks, etc.		
Standard Specifications for Cold Water Meters (3) ($0.20 each)		
Standard Specification for Threads for Underground Service Line Fittings		
Microscopy of Drinking Water (4th Ed. $7.50)	John Wiley & Sons, New York City	Whipple-Fair
pH Control (F)	W. A. Taylor Co., Baltimore, Md.	
Plane Surveying ($5.50)	John Wiley & Sons, New York City	Tracy
Plumber's Handbook ($4.00)	McGraw-Hill Co., New York City	Dibble
Public Water Supplies—4th Ed. ($6.50)	John Wiley & Sons, New York City	Turneaure & Russell
Reference Bibliography for Water and Sewage Works	Gilbert Associates, Inc., Reading, Pa.	
Stand. Meth. of Wtr. and Sewage Anal., 9th Ed. ($4.00)	A. P. H. A. and A. W. W. A., New York City	Various
Taste and Odor Control in Water Purification (F)	Industrial Chem. Sales Div., New York 17, N. Y.	
Technical Bulletins on Chlorination (F)	Wallace & Tiernan Co., Newark, N. J.	Various
The Operation of Water Filtration Plants (F)	N. C. State Dept. Health, Raleigh, N. C.	
Water Purification ($7.00)	McGraw-Hill Co., New York City	Ellms
Water Purification Control, 3rd Edition	Williams & Wilkins, Baltimore, Md.	Hopkins
Water Purification for Plant Operators ($2.50)	McGraw-Hill Co., New York City	Norcom and Brown
Water Rate Structures in America (F)	Public Service Commission of Wisconsin, Madison, Wis.	
Water Supply & Treatment, 3rd Ed. ($0.75)	National Lime Assn., Washington, D. C.	Hoover
Water Supply Control (nominal charge)	N. Y. State Dept. Health, Albany, N. Y.	
Water Treatment and Purification 2nd Ed. ($2.75)	McGraw-Hill Co., New York City	Ryan
Water Works Engineering in Disaster (F)	O.C.D. Pub. No. 2022, Washington, D. C.	McCallum
Water Works Handbook ($7.00)	McGraw-Hill Co., New York City	Flynn, Weston & Bogert

(F) Available as Free Publication at this writing.

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS

(In addition to List No. 1)

Books	*Publishers*	*Authors*
Applied Hydraulics ($7.50)	John Wiley & Sons, Inc., New York City	Addison
Bibliography on Water & Sewage Analysis	Ga. Inst. Tech	Weil, Murray & Reid
Boiler Feedwater Purification ($4.00)	McGraw-Hill Co., New York City	Powell
Business Administration for Engineers ($5.00)	McGraw-Hill Co., New York City	Harding & Canfield
Business Law for Engineers ($4.00)	McGraw-Hill Co., New York City	Allen
Civil Engineering Handbook—3rd Ed. ($10.00)	McGraw-Hill Co., New York City	Urquhart
Concrete Engineers' Handbook ($6.00)	McGraw-Hill Co., New York City	Hool & Johnson
Corrosion; Causes and Prevention ($7.00)	John Wiley & Sons, Inc., New York City	Uhlig
Corrosion Handbook ($12.00)	McGraw-Hill Co., New York City	Speller
Data Book on Design for Civil Engineers (3 Vols.)	John Wiley & Sons, Inc., New York City	Elwyn E. Seelye
Deep Well Drilling	The Gulf Publishing Co., Houston, Tex.	Walter & Jeffery
Design of Dams ($5.00)	McGraw-Hill Book Co., New York City	Hanna and Kennedy
Elimination of Tastes and Odors in Water ($5.00)	McGraw-Hill Co., New York City	Bayfis
Financial Administration of Municipal Utilities ($3.75)	Public Administration Service	Tenner
Fresh Water Biology ($8.00)	John Wiley & Sons, New York City	Ward & Whipple
Fresh Water Algae ($6.00)	McGraw-Hill Co., New York City	Smith
Geomorphology	McGraw-Hill Book Co., Inc., New York City	A. K. Lobeck
Ground Water ($6.00)	McGraw-Hill Book Co., New York City	C. F. Tolman

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS (Con't.)

Books	*Publishers*	*Authors*
Ground Water, Its Development, Uses & Conservation	Edward E. Johnson, Inc., St. Paul, Minn.	Bennison
Guiding Principles of Public Service Reg. (3 Vols.)	Public Utilities Reports, Inc., Rochester, N. Y.	Spurr
Handbook of Applied Hydraulics ($7.50)	McGraw-Hill Co., New York City	Davis
Hydraulics 5th Ed. ($4.00)	McGraw-Hill Co., New York City	King
Index to Jour. of A. W. W. A.—1881-1933 ($2.00)	Am. Water Wks. Assn., New York City	
"Industrial Water Supplies" (nominal charge)	Ohio Geological Survey, Columbus, Ohio	C. W. Foulk
Laboratory Control of Water Purification ($4.00)	Case, Sheppard, Mann Pub. Co., New York 18, N. Y.	Cox
Mechanical Engineers' Handbook—11th Ed. ($6.00)	John Wiley & Sons, New York City	Kent
pH and Its Practical Application ($3.50)	Williams & Wilkins Co., Baltimore, Md.	LaMotte, Kenny & Reed
Physics of the Earth IX	McGraw-Hill Book Co., Inc., New York City	Oscar E. Meinzer
Plumbing Engineering ($3.50)	Pittman Publishing Co., New York	Cleverdon
Pocket Companion (nominal)	Carnegie-Steel Corp., New York City	
Public Health Engineering—Vol. I ($7.50)	John Wiley & Sons, Inc., New York 16, N. Y.	Phelps
Public Utility Rate Structures ($4.00)	McGraw-Hill Co., New York City	Nash
Pump Handbook	National Press, Millbrae, Calif.	Finch
Rainfall and Runoff ($9.00)	MacMillan Co., New York City	Foster
Rates and Rate Structure	Ohio State Univ., Columbus, O.	Jt. Comm. ABA, ASCE, AWWA, FISWA
Standards of Hydraulic Institute—8th Ed. ($3.00)	Hydraulic Institute, New York 6, N. Y.	
Standard Practices for Stationary Diesel Engines ($2.50)	Diesel Engine Mfg. Assn., Chicago, Ill.	
Summary of Census Data on Water Treatment Plants in the United States	Am. Water Works Assn. Reprint	U. S. Pub. Health Service
Textbook of Bacteriology ($8.00)	D. Appleton & Co., New York City	Zinser & Jones
The Hardy Cross Method of Distribution System Design	Univ. of Illinois Engr. Exp. Sta. Bul. No. 286	Hardy Cross
The Quest for Pure Water ($5.00)	Amer. Water Wks. Assn., New York 7, N. Y.	Baker
Valve Manual ($2.00)	Mo. Water & Sew. Conf.	Lischer
Water Bacteriology—6th Ed. ($4.50)	John Wiley & Sons, New York 16, N. Y.	Prescott, Winslow & McCrady
Water Borne Typhoid Fever Outbreaks (nominal)	Am. Public Health Assn., N. Y. C.	Wolman & Gorman
Water Quality & Treatment—2nd Ed. ($5.00)	A.W.W.A.	
Water Supply and Sewerage ($5.00)	McGraw-Hill Co., New York City	Steel
Water Supply Engineering (4th Ed. $6.50)	McGraw-Hill Co., New York City	Babbitt & Doland
Water Supply Paper No. 658 (Quality of Waters)	U. S. Geological Survey, Washington, D. C.	Stabler

LIST NO. 3—FOR OPERATORS AND MANAGERS OF SMALL SEWAGE WORKS**

Books	*Publisher*	*Authors*
Chemical Treatment of Sewage (nominal)	Amer. Pub. Health Assn., N. Y. C.	Committee Report
Chlorine Manual (F)	The Chlorine Institute, New York 17, N. Y.	
Lab. Manual of Water and Sewage Anal. 3rd Ed. ($3.00)	McGraw-Hill Co., New York City	Theroux, Eldridge & Mallman
Manual for Sewage Plant Operators ($3.50)	Texas Water & Sewage Wks. Assn., c/o State Dept. of Health	
Manuals of the Federation of Sewage Works Assns.	Champaign, Ill.	
Chlorination of Sewage and Industrial Wastes Municipal Sewer Ordinances Occupational Hazards in Operation of Sewage Works Utilization of Sewage Sludge as Fertilizer		
Operation and Control of Sewage Treatment Plants	New York State Dept. Health	N. Y. State Dept. Health
Principles of Sewage Treatment ($0.50)	National Lime Assn., Washington, D. C.	W. Rudolfs and Staff
Reference Bibliography for Water and Sewage	Gilbert Associates, Inc., Reading, Pa.	
Reprints of Technical Papers on Chlorine in Sewage Treatment (F)	Wallace & Tiernan Co., Newark, N. J.	Various
Sewage Treatment ($3.50)	John Wiley & Sons, Inc., New York City	Imhoff and Fair
Sewage Treatment Works ($6.00)	McGraw-Hill Book Co., New York City	Keefer
Sewerage and Sewage Disposal Textbook ($6.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Sewer Rentals ($1.50)	Am. Public Works Assn., Chicago	Various
Stand. Meth. of Water and Sewage Analysis, 9th Ed. ($4.00)	Amer. Pub. Health Assn., N. Y. C.	A. W. W. A.-A. P. H. A.

****Note**—Sewage works men should examine Lists 1 and 2—also for several (F) publications of value to all alike—for instance, "Conversion Factors for Engineers" and the handbooks.

LIST NO. 4—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE SEWAGE WORKS**

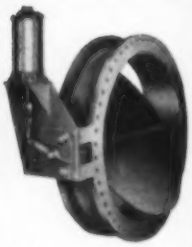
(In addition to List No. 3)

Books	*Publishers*	*Authors*
American Sewage Practice Vol. 3, Sewage Treatment ($7.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Industrial Waste Treatment Practice ($5.00)	McGraw-Hill Co., New York City	Eldridge
Modern Sewage Disposal ($3.50)****	Federation of Sewage Works Assns., New York City	Various
Municipal and Rural Sanitation, 3rd Ed.	McGraw-Hill Book Co., Inc., New York City	Ehlers & Steel
Public Health Engineering—Vol. I ($7.50)	John Wiley & Sons, Inc., New York 16, N. Y.	Phelps
Rates and Rate Structures	Ohio State Univ., Columbus, O.	Jt. Comm. ABA, ASCE, AWWA, FISWA
Sewage Trade Waste Treatment	Govt. Printer, Adelaide, Australia	Henry J. N. Hodgson
Sewerage and Sewage Treatment—2nd Ed. ($4.00)	Intl. Text Book Co., Scranton, Pa.	Hardenberg
Sewerage and Sewage Treatment—6th Ed. ($6.50)	John Wiley & Sons, New York City	Babbitt
Sewers (25 shillings)	Chapman & Hall, London	Bevan and Rees
Solving Sewage Problems ($6.00)	McGraw-Hill Co., New York City	Fuller & McClintock
Stream Sanitation ($3.50)	John Wiley & Sons, Inc., New York 16, N. Y.	Phelps
The Hoover Plumbing Code (B. H. 13) (nominal)	U. S. Bureau of Standards	

(F) Available as Free Publication at this writing.

No. 797—24-inch heavy duty electric motor operated valve. Handwheel for manual use in case of current failure.

No. 700—20-inch class "B" cast iron valve equipped with heavy duty handwheel control and threaded reach rod.

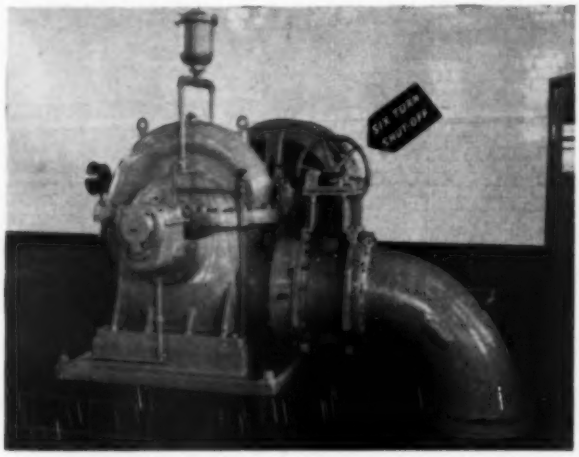


No. 627—Cylinder operated 60-inch heavy duty valve (either pneumatic or hydraulic control).

R-S Valves are synonymous with the simplified control and shut-off of any material that flows or is forced through a pipe, under a wide range of pressure and temperature.

R-S valvEvents

• EXCERPTS FROM THE R-S BOOK OF EXPERIENCE •



ATLANTIC CITY Simplifies PUMP SHUT-OFF

New pumping units of the modern Atlantic City Pumping Station supplying water for this seashore resort are equipped with 125-pound handwheel operated R-S valves.

The valve illustrated above is closed in a matter of seconds (only six handwheel revolutions required) before the pump is started in order to prevent an overload on the pump and motor. The valve is then opened gradually and easily regulated according to demand.

Such valves can be equipped with hydraulic cylinders (tapped into the pipe line before and after the pump). As long as the differential pressure remains above a predetermined value, the cylinder will hold the valve open. Power or mechanical failure will cause a drop in the differential pressure, and the cylinder will close the valve automatically. Water hammer is impossible since the valve closes only as fast as the adjustable cylinder bleeds.

Specify R-S Valves for simplified construction and operation.

R-S PRODUCTS CORPORATION
4600 Germantown Avenue, Philadelphia 44, Pa.
An S. Morgan Smith Company Subsidiary

DISTRICT OFFICES IN PRINCIPAL CITIES

THE DISTRIBUTION SYSTEM*

By L. R. HOWSON
Consulting Engineer
Alvord, Burdick & Howson, Chicago, Ill.

IN ENDEAVORING to appraise the importance of the distribution system in water works practice, I first turned to the Journals of the American Water Works Association, an inspection of which disclosed that there were over twice as many papers relating to water quality and water treatment as there were with reference to the distribution system, including meters, unaccounted for water, hydrants and valves. Probably this is as it should be, for water quality is a matter of life and death; whereas proper design, operation and maintenance of a distribution system is primarily a question of economics. Undoubtedly this seeming lack of proper consideration for the economics of water supply results from the inability of the various program committees to secure constructive papers on what is generally considered a prosaic subject.

Economic Value of Distribution Systems

As a second step in appraising the economic importance of the water distribution system, the summaries of 16 recent water works appraisals were analyzed. The analyses showed that for these 16 plants the distribution system valuation averaged 66.8 per cent of the total plant value. While this percentage varied somewhat for individual plants, all but two fell within a range of 20 per cent of this numerical average. The weighted average of the percentage of the distribution value to the total plant value of the 16 plants was 65.3 per cent. It may be roughly stated, therefore, that two-thirds of the total value of the average water works is found in the distribution system. A check of valuations made as remote as thirty years ago shows this ratio to have remained practically constant.

The fact that two-thirds of the value of the ordinary water works is in the distribution system, and that 80 per cent of the distribution system value is in the item of mains and valves, indicates one of the most valuable yardsticks for an approximate indication of the value of a water works property of which there is no detailed inventory available. The length of pipe of the various sizes in the distribution system is always a matter of record and capable of easy conversion into tons. Normally the weight of pipe in a cast-iron distribution system will approximate 275 to 300 tons per thousand population.

Analysis of nine recent water works valuations, most of which involved transfer of ownership, revealed that the value of the entire system per ton of pipe in the distribution system was approximately $200. Cities with well supplies or without treatment will normally fall somewhat under the $200 per ton, and those with impounded supplies and costly purification works will be normally somewhat above the $200 per ton figure. The application of this figure, however, varied with respect to the facts relating to the source of supply in each particular case, will give a convenient and very approximate indication of the valuation of the entire water works property at the present time.

An analysis of these same nine water works valuations showed that the average per capital value as of the present time was $63. Since two-thirds of the value of a water works system is normally in the distribution system, it is apparent that the present-day distribution system in the average city has a value equivalent to about $40 per capita.

Some Basic Factors in Design

Too many distribution systems just grow. Very few distribution systems were scientifically designed originally; and through growth, concentration and shifting demands most systems need almost constant checking. The problem of designing an entirely new distribution system is seldom met in practice. The more frequent problem is that of designing a feeder or circulating system to correct deficiencies in capacity resulting from growth, reduction in carrying capacity, or allied causes. The National Board of Fire Underwriters, through periodic tests of distribution systems, has done much to uncover weaknesses and to indicate the requirements for reinforcement.

Every water distribution system supplies two distinct services; namely, the furnishing of normal domestic and industrial requirements and the water required to fight fires.

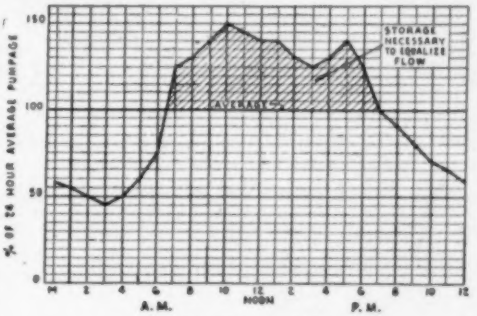
The former type of service extends more or less continuously over the entire area served. Fire demands are intermittent, concentrated in relatively small areas and of high intensity.

The domestic and industrial needs for water vary from day to day and from hour to hour. Ordinarily the maximum day of the year will be 50 per cent more or less in excess of the average day for the year, and on that maximum day, the peak hour will be 50 per cent more or less above the 24-hour average. Accordingly, the annual peak is approximately 2¼ times the average rate for the year. These percentages are subject to material variations for various cities but are sufficiently accurate for use in illustrating the comparative importance of ordinary and fire demands on the distribution system.

Elevated Tank Storage

The fact that the maximum rates prevail during but a portion of the day makes it possible to provide for them in whole or in part by storage in reservoirs or elevated tanks. Ordinarily, if elevated storage of from 20 to 40 gallons per capita (gpc.) is available, the rate of pumpage can be constant throughout the 24 hours of the day with all peaks met with water drawn from storage. It is, however, not necessary to provide storage in this amount to secure most of the benefits. Storage in the amount of but 25 per cent of the total storage requirement will ordinarily result in lowering the peak rate of pumpage by half its excess over the daily average. This 25 per cent storage provision is equivalent to only 5 to 10 gallons storage per capita.

Elevated tank storage sufficient to completely iron out hourly peaks is not very costly. Assuming 30 gpc. as the storage required in order that the supply and pumping equipment may operate at a uniform rate throughout the 24 hours of the day, the approximate present-day costs would be as follows:



Typical Hourly Pumpage Rates

Population	Elevated Tank Capacity	Elevated Tank Cost @ 12c/lb.	% Tank Cost to Value of Distr. System
5,000	150,000	18,000	9
25,000	750,000	69,000	6.9
50,000	1,500,000	132,000	6.6
100,000	3,000,000	250,000	6.25
200,000	6,000,000	500,000	6.25

The most of adequate elevated storage is thus from $2.50 to $3.60 per capita. Interest and depreciation at 6 per cent on this cost for municipal plants is but from 15 to 22 cents per capita per year, the equivalent of from 25 to 35 per cent of the average power cost where pumping is by electricity. Ability to avoid peak demand charges will frequently cover much of the fixed charges on the investment in elevated storage. The other benefits such as more uniform pressures, better operations of pumping

*A paper presented before the Wisconsin Section of A.W.W.A., the publication of which has been authorized by the Association.

equipment and safety against power outages, amply justify elevated storage in most water systems. The amount of elevated storage in each case is, of course, dictated by the individual conditions. The above is simply indicative of the possibilities to be developed.

Firefighting Considerations and Storage Costs

In addition to meeting all variations in domestic, commercial and industrial demands, a distribution system must be so designed as to transport the volume of water required for fighting fires. The rate at which water is required for fire service is a reflection of the character of development, whether suburban or metropolitan, fire hazards, and so forth. It varies approximately as the square root of population in thousands and is, therefore, proportionately greater for smaller communities. The following table gives the amount of water required by the National Board of Fire Underwriters for fighting fires in cities of various sizes:

Population	Fire Demand (GPM)
5,000	3,250
25,000	4,750
50,000	6,500
100,000	9,000
200,000	12,000

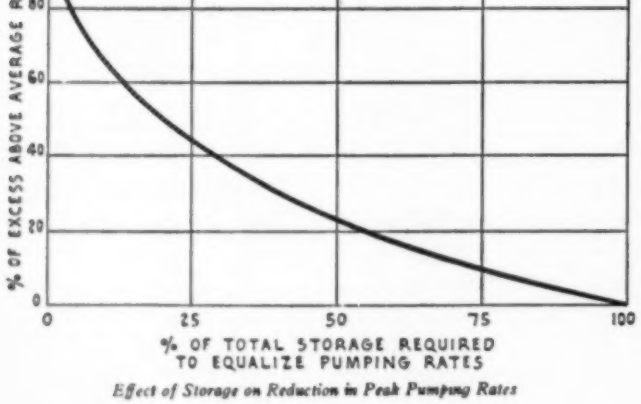
The above quantities are required in addition to the ordinary uses at the time, usually considered as 150 per cent of the average for the 24 hours.

Fortunately, fires do not occur at frequent intervals but they do occur with sufficient frequency and intensity to demonstrate the wisdom of making adequate provision for them. The extinguishment of fires ordinarily uses less than one-half of 1 per cent of the total pumpage.

The fact that fires are relatively of short duration indicates the possibility of storage to provide the water required for fighting fires, thus avoiding sudden extreme drafts upon water production systems. The accompanying table shows the fire demand rate, the volume of water required during 10 hours at the several rates (Underwriter's requirement), and the estimated cost of reinforced concrete reservoir construction to store the fire requirements for cities of various populations; and the ratio of reservoir cost to distribution system value.

Population	10 Hour Fire Use (Gallons)	Cost of Reinforced Concrete Reservoir*	Ratio of Reservoir Cost to Distribution System Value
5,000	1,350,000	$ 55,000	27.5%
25,000	2,750,000	93,000	9.2%
50,000	3,900,000	113,000	5.65%
100,000	5,400,000	135,000	2.37%
200,000	7,200,000	168,000	1.97%

*To store fire requirement—such costs being based on E.N.R. Construction Cost Index = 350.



Effect of Storage on Reduction in Peak Pumping Rates

If the topography is such that reservoir storage equal to the fire use can be so located as to float on the distribution system, it will relieve the source of supply, pumping equipment and distribution system of the fire demand and thus affect the total valuation of $63 per capita. It is also available and useful for domestic peaks at all times without cost other than interest and depreciation on the investment.

If the reservoir is built at ground level comparable to the station, but at a point near the opposite end of the distribution system from the pumping station, it is of value to the source of supply and the mains but duplicate pumping equipment will be required. A reservoir of this kind benefits about 90 per cent of the plant valuation when used during fire, but is of less value during other periods as booster pumps must be operated to make its benefits available.

If the water required to fight fires is stored in a low service reservoir or clear well at the pumping station, its effect is limited to the source of supply; i.e., usually less than 25 per cent of the property valuation.

An elevated tank to store the quantity of water required for fire in a 5,000 town would cost about $115,000. Since such a figure represents about 60 per cent of the value of the entire distribution system, it is evident that the primary justification for the elevated tank in the smaller systems is in equalizing hourly variations in domestic use.

The ratio of the water required for fire protection, and for peak domestic uses, is shown as follows:

Population	Peak Domestic Rate @ 225% of 100 gpc/day	150% Domestic plus Fire	Ratio Fire to Domestic Peak
5,000	1,125,000	4,250,000	3.7
25,000	5,625,000	10,600,000	1.88
50,000	11,250,000	17,000,000	1.51
100,000	22,500,000	27,900,000	1.24
200,000	45,000,000	47,300,000	1.05

It will be noted that for a city of 5,000, the peak demand during fire, which is based upon the fire use plus 150 per cent of the average day domestic, is 3.7 times as great as the peak hour domestic use; decreasing progressively to 1.88 for 25,000 population, 1.51 for 50,000, 1.24 for 100,000, and 1.05 for 200,000. In other words, for a city of approximately 200,000 population or larger, the peak domestic use rather than the fire requirement determines the size of the distribution system. For all populations less than 20,000 the fire requirement is the governing factor in the design of the distribution system.

Sizes of Mains

A water works distribution system consists of feeder mains and lateral distributors to serve consumers. The proportion of the total flow during fire which is carried through the laterals may vary from a negligible amount where the lateral system consists of 4-in. mains or smaller to a material proportion where the lateral distributors are 6-in. or larger. In order to ascertain how the pipe sizes vary in the average distribution system, the pipe systems of eight cities varying in population from 5,000 to 300,000 were studied. In the average of these systems, approximately 55 per cent of the mileage of mains was 6-in. in diameter with 15 per cent 4-in., another 15 per cent 8-in., and about half of the remainder 12-in. The weighted average size obtained by multiplying the footage of each size by its diameter and dividing the sum of the totals by the lineal feet, is approximately 7-in. This weighted average diameter varied but little between the eight systems, the maximum variation being not more than 5 per cent either way.

A few cities such as Des Moines, Iowa, have in recent years adopted 8-in. as the minimum size to use, in which case the proportion and capacities of feeder mains is less and the weighted average size of the mains larger. However, in very few cities does the weighted average size of mains materially exceed 7-in.

(*Continued on page 25*)

UNITED STATES PIPE AND FOUNDRY CO.

General Offices: **Burlington, New Jersey**

SALES OFFICES

Philadelphia, New York, Birmingham, Chicago, San Francisco, Boston, Pittsburgh, Kansas City, Cleveland, Dallas, Minneapolis, Houston, Seattle, Los Angeles

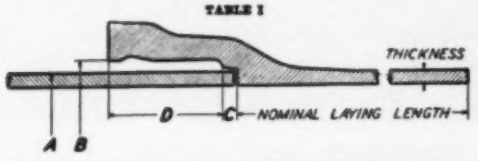
Makers of

SUPER-DE LAVAUD CENTRIFUGALLY CAST IRON PIPE
PIT CAST IRON PIPE AND FITTINGS
U. S. STANDARDIZED MECHANICAL JOINT PIPE
THREADED PIPE IN IRON PIPE SIZES
WEBRE INDUSTRIAL AND SUGAR APPARATUS
FLANGED PIPE AND FITTINGS
FLEXIBLE JOINT PIPE
LARGE CASTINGS TO ORDER
USICAST CHEMICAL CASTINGS

Super deLavaud Pipe with B&S Joints

Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3" to 24" and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-de Lavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length 12-Foot Length: Weight of Pipe Pounds	12-Foot Length: Weight Per Foot Including Bell	18-Foot Length: Weight of Pipe Pounds	18-Foot Length: Weight Per Foot Including Bell
3	150	.33	150	12.7	225	12.4
3	250	.38	165	13.7	240	13.4
4	150	.34	195	18.4	285	16.9
4	250	.38	220	18.4	325	17.9
6	150	.37	315	28.3	460	25.5
6	250	.43	350	29.3	515	28.5
8	150	.42	475	39.4	690	38.3
8	200	.46	510	42.4	745	41.3
8	250	.50	545	45.5	800	44.3
10	150	.47	640	53.2	935	51.8
10	200	.53	700	58.3	1025	56.9
10	250	.57	760	63.3	1115	61.9
12	150	.50	810	67.4	1190	65.6
12	200	.57	905	75.4	1325	73.7
12	250	.63	990	82.5	1450	80.7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length 12-Foot Length: Weight of Pipe Pounds	12-Foot Length: Weight Per Foot Including Bell	18-Foot Length: Weight of Pipe Pounds	18-Foot Length: Weight Per Foot Including Bell
14	100	.48	920	76.8	1340	74.3
14	150	.55	1060	88.5	1555	86.3
14	200	.62	1180	99.0	1735	96.5
14	250	.69	1320	110.0	1930	107.3
16	100	.53	1130	94.2	1645	91.4
16	150	.60	1320	110.3	1935	107.4
16	200	.68	1490	124.1	2175	120.7
16	250	.76	1635	136.1	2380	132.7
18	100	.58	1365	113.0	1990	110.6
18	150	.65	1585	132.8	2330	129.6
18	200	.74	1810	150.9	2645	146.9
18	250	.83	2015	168.0	2950	163.9
20	100	.68	1585	132.0	2305	128.0
20	150	.68	1860	156.0	2720	151.0
20	200	.78	2136	177.1	3105	172.4
20	250	.88	2385	197.1	3465	192.4
24	100	.84	2058	172.8	3035	168.6
24	150	.78	2480	206.6	3630	201.6
24	200	.88	2854	237.8	4170	231.6
24	250	1.00	3300	260.6	4680	260.6

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "iron pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Federal Specifications WW-P-356.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per foot Pounds
3	Standard	12	3.50	.36	8	11.08
	X-strong	12	3.50	.46	8	13.45
	XX-strong	12	3.50	.68	8	18.21
4	Standard	12	4.50	.38	8	15.14
	X-strong	12	4.50	.46	8	18.01
	XX-strong	12	4.50	.62	8	23.29
5	Standard	12	5.56	.40	8	20.22
	X-strong	12	5.56	.49	8	24.40
	XX-strong	12	5.56	.55	8	28.16
6	Standard	12	6.63	.43	8	26.13
	X-strong	12	6.63	.51	8	30.49
	XX-strong	12	6.63	.65	8	33.78
8	Standard	12	8.63	.50	8	39.85
	X-strong	12	8.63	.56	8	44.39
	XX-strong	12	8.63	.80	8	47.32

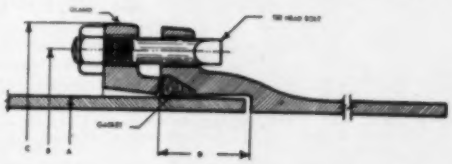
THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	12	3.50	.26	8	9.41
4	12	4.50	.28	8	11.75
5	12	5.56	.32	8	15.85
6	12	6.63	.36	8	20.22
8	12	8.63	.44	8	30.62

U. S. STANDARDIZED MECHANICAL JOINT



We are now prepared to furnish U. S. Standardized Mechanical Joint Pipe and Fittings in sizes from 3" to 24" with parts that are interchangeable with those furnished by other manufacturers of cast iron mechanical joint pipe.

Johns-Manville

Manufacturers of "Transite" Pressure Pipe

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*District Office

Here's How TRANSITE PRESSURE PIPE Meets These 7 Basic Water Line Problems . . .

IF YOU are faced with some—or all—of these 7 common water-line problems, here is information about Johns-Manville Transite* Pressure Pipe that may be of help to you...facts that tell how this modern asbestos-cement pipe is helping to solve these problems in many communities.

1. Handling costs:

Because it is light in weight and easy to handle, Transite Pressure Pipe keeps handling costs down. Loading, unloading, and all other subsequent handling operations are simplified. More footage can be hauled per truck-load—reducing trucking costs—and distribution along the trench is easier and more quickly accomplished. Moreover, mechanical handling equipment is not necessary except where larger sizes are being used; the pipe sections are easily lowered into the trench with rope slings.

2. Installation costs:

Transite Pressure Pipe offers important economies that help combat increasing costs of water-line installation. It is quickly and easily assembled in the trench. A coupling puller is the only tool necessary. Often, the pipe can be assembled so rapidly that the same foreman supervises both excavation and installation. The speed with which Transite is assembled means that the job is completed with a minimum of time and labor, thereby contributing important reductions in the overall cost of the system.

*Transite is a Johns-Manville registered trade mark

3. Soil corrosion:

Two factors give Transite Pressure Pipe exceptional resistance to corrosion: (1) the corrosion-resistant materials of which it is made; (2) the especially developed Johns-Manville process of manufacture which imparts a high degree of chemical stability to the finished pipe. This high resistance to corrosion has been substantiated by numerous installations. Many of these are serving as replacements in soils so destructive that the useful life of the pipe materials previously used had been seriously curtailed.

4. Internal corrosion:

Transite Pipe, because of its asbestos-cement composition, is not affected by tuberculation. Therefore, it is not necessary to resort to pipe of larger diameter to offset the internal effects of this costly form of pipe corrosion. And because progressive reduction of delivery due to tuberculation capacity is never a problem in a Transite pipe line, pressures and flows remain high—pumps operate at higher efficiencies. These factors are often reflected in better service and lower water rates in communities served by Transite lines.

5. Underground water losses:

Transite's success in combatting underground water losses is due to a combination of two factors: (1) the design of the Simplex Coupling used for assembly; and (2) the ability of the pipe to maintain its strength in service. The easily-assembled Coupling consists of a Transite sleeve and two rubber rings which form a tight, flexible joint. The ability of Transite to maintain its strength in service is due to its exceptional resistance to corrosion, as proved in thousands of installations under a wide variety of soil conditions.

6. Vibration and stresses:

Transite's flexible joints effectively absorb the vibration of heavy traffic—an especially important factor where pipe is laid under busy highways, or near railroad and street car tracks. Because each joint is capable of deflection up to five degrees, the entire line has a flexibility not ordinarily found in other types of waterline construction. This helps compensate for soil movements and other stresses to which the pipe may be subjected . . . provides an effective safeguard against costly pipe failures.

7. Maintenance:

In thousands of communities, Transite Pipe—with its advantages of joints that remain tight and flexible, its corrosion resistance, and immunity to tuberculation—provides low-cost water transportation that requires little, if any, maintenance. Transite lines do not have to be cleaned, lined, or replaced because tuberculation has reduced their original capacity. Reports from communities all over the country prove that Transite's asbestos-cement structure provides economies that continue through the years.

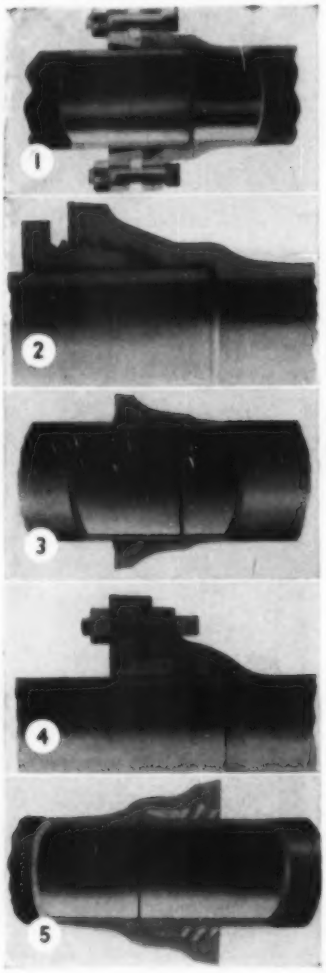
CLASSES, STANDARD SIZES AND APPROXIMATE WEIGHTS OF TRANSITE PRESSURE PIPE

Class (maximum recommended working pressure, psi)	Equivalent head, feet of water	Nominal inside diameter, in.						
		4	6	8	10	12	14	16
		Pounds per linear foot including coupling and rubber rings						
100	231	6.4	10.8	16.0	22.8	30.4	39.2	51.3
150	346	7.6	13.0	19.8	31.9	43.3	57.7	72.5

MONO-CAST CENTRIFUGAL PIPE

WITH JOINTS FOR EVERY SERVICE CONDITION

Mono-Cast Centrifugal Pipe can be supplied with joints for conveying gas, oil, sewage, water, and other liquids under every service condition. In most cases, these joints can be made up with unskilled labor and without special tools. Among the joints available are:



1. **AMERICAN DOUBLE-X PIPE**—A standardized *mechanical joint pipe* equipped with stuffing box type of joint having a ring gasket, cast iron gland, and cast iron bolts. Scientifically designed to meet the exacting requirements of low, medium and high-pressure service in handling gas and liquids.

2. **SCREW-GLAND PIPE**—An all-purpose economical, mechanical joint pipe suitable for water, gas, oil and other fluids, developed in answer to the demand for a rubber packed joint without bolts suitable for normal service and pressure conditions. Screw-Gland Pipe provides for liberal lateral deflection and provision for expansion and contraction of the pipe line without leakage.

3. **ROLL-ON JOINT PIPE**—Designed as an alternate for bell and spigot pipe for conveyance of water, sewage or similar liquids. It is quickly and easily assembled by unskilled labor and after assembly the joint will easily deflect and remain tight under pressure.

4. **MOLOX BALL JOINT PIPE**—An exclusive Acipco development, designed for river crossings and other installations requiring excessive joint deflection. It is positively locked against joint separation and remains bottle tight under pressures up to several hundred pounds per square inch at any angle within the range of deflection for which it is designed.

5. **STANDARD BELL AND SPIGOT PIPE**—Used under normal service conditions, the standard bell and spigot joint will give long and dependable service. The joints of bell and spigot pipe are made up of lead and jute, cement, or any other special jointing material customer may desire to use. It is supplied in diameters 3″ through 48″ inclusive.

Write for literature, stating the kind of joint in which you are interested. Address the ACIPCO office nearest you.

AMERICAN CAST IRON PIPE COMPANY

BIRMINGHAM 2, ALABAMA

Dallas	Houston	El Paso	Pittsburgh	Kansas City	New York City
Chicago	Minneapolis	Cleveland	Los Angeles	San Francisco	Seattle

(Continued from page 20)

Larger diameters of pipe provide more carrying capacity per dollar expended, as is shown by the following table:

Diam. of pipe	Comparative Carrying Capacity*	Cost per foot Installed	Relation of cost to Capacity
4"	100	$1.10	1.1
6"	292	1.50	.52
8"	620	1.95	.31
12"	1,800	3.10	.17
16"	3,850	4.60	.12
20"	6,950	6.35	.09

*Based upon C = 120 of Hazen-Williams formula and pressure drop of 8 ft. per 1,000 ft.

The above estimates of cost are based upon Class B pipe at $50 per ton and costs of laying, which were the average of those used in six recent mid-western appraisals.

From an analysis of the above, it is apparent that a 6-in. main costs about 36 per cent more than a 4-in., but with the same friction loss will deliver 192 per cent more water. Correspondingly, an 8-in., which costs 30 per cent more than 6-in., will deliver 112 per cent more water, and a 12-in., which costs 59 per cent more than an 8-in., will deliver 191 per cent more water. Expressed in another way, increasing the pipe diameter by one size increases the carrying capacity from three to four times as much as the proportionate increase in cost.

Effect of Elevated Storage on Expenditures for Feeder Main

As a general line of demarcation it may be assumed that, in the ordinary distribution system, mains 6-in. in diameter and smaller primarily serve the normal domestic requirements; and that mains 8-in. and larger, in addition to serving these requirements, have been so designed as to provide a circulatory or feeder system to carry the water from the pumping station or reservoirs to the smaller distributing mains. The beneficial effects of elevated storage are, therefore, primarily limited to mains 8-in. and larger.

As stated, approximately 70 per cent of the footage of mains in the average distribution system is 6-in. or less in diameter. However, the mains of larger diameter cost more per foot, and an analysis of a considerable number of distribution systems shows that approximately 45 per cent of the value of the distribution system is in mains 8-in. and larger.

The value of the mains over 8-in. in diameter in the average distribution system is approximately $15 per capita.

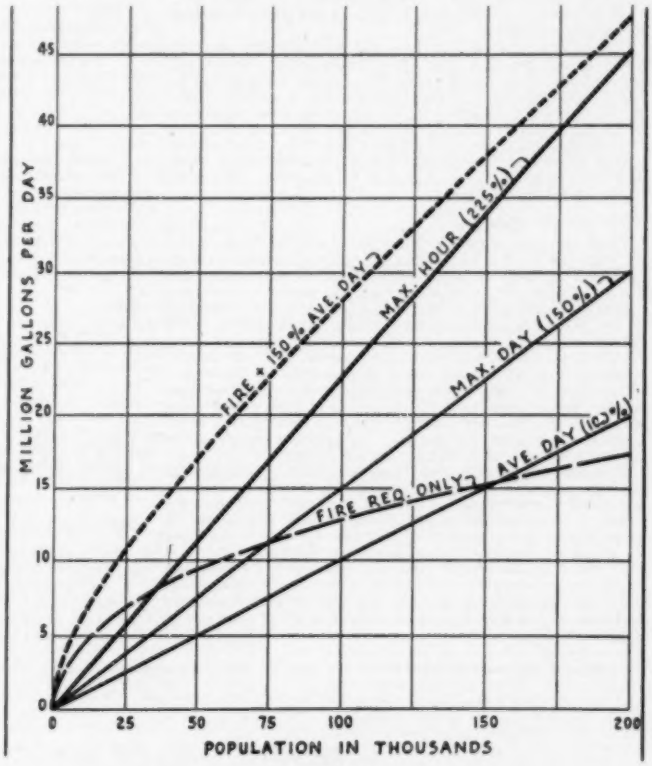
This value may be developed from the above figures on (1) the value of the average entire water works system at the present time, (2) the proportion of that value which is in the distribution system, (3) the proportion of the distribution system which is accounted for by mains, and (4) the percentage of total main value in mains larger than 8-in. In a city of 25,000 people the value of mains 8-in. and larger might be expected to be approximately $375,000.

Elevated storage sufficient to iron out the daily variations in flow in the average city of 25,000 population would cost approximately $69,000 at the present time, the equivalent of 18 per cent of the investment in feeder mains 8-in. and larger. If the topography is such that this peak requirement could be stored in a concrete reservoir at sufficient elevation, and not too distant, it would cost $36,000. This is less than 10 per cent of the investment in feeder mains.

There is obviously no general rule that can be laid down as applicable to all cities. In a recent study for a city where topography is such that strategically located reservoir storage could be provided within the area served by the distribution system, the provision of storage sufficient to provide for both domestic peaks and fire requirements cost approximately 30 per cent of the investment in feeder mains, and less than the expenditures required without storage for the proper reinforcement of the feeder main system.

Loss in Carrying Capacity

Another factor which has had a large effect on distribution system design has been the necessity of anticipating a loss in carrying capacity with the passage of time. The extent of this loss was evaluated by Edgar K. Wilson (Jour. AWWA, Vol. 28, No. 9), who showed that for midwestern waters in general, the Hazen-Williams coefficient decreased from 130 when new to 100 in about 20 years; a loss averaging more than one per cent per year. If such loss in carrying capacity were reflected in a comparable loss in valuation, this would be equivalent to a per capita loss of approximately $10 in a 20-year period, or 50 cents per capita per year, or nearly 10 per cent of the gross revenues of the average water utility.



Water Demand Rates
Domestic, 24-Hour Fire and Combined Fire and Domestic

Fortunately, this loss in carrying capacity is not correspondingly reflected in value. It is practicable to restore the carrying capacity to substantially its initial value by cleaning. Taking the average distribution system, the cost of such cleaning is approximately 5 per cent of the cost of the pipe installed new. Cleaning an entire system is seldom, if ever, resorted to. When main cleaning is done, it is usually confined to the feeder and circulating pipes where relation of cleaning to installation cost is even less than 5 per cent.

Loss of capacity, however, is a serious indictment of the water works industry. Certainly some method of protecting so large a proportion of the total water works investment should be available at reasonable cost. It is rather surprising that the heavier cement linings have not been more largely adopted. The cost of heavy cement lining varies from 6½ cents per ft. for 6-in. pipe to 26 cents per ft. for 20-in. pipe, equivalent to approximately 5 per cent of the cost of the pipe installed. If its use will maintain the carrying capacity of pipe (as seems probable

in most cases) its cost is well justified. Many designers have figured pipe sizes using Hazen-Williams coefficient of 100 instead of 130, in anticipation of loss in capacity. The cost of this excess capacity exceeds that of cement lining. Cement lining costs about the same as one cleaning but is better because it maintains capacity, whereas cleaning only periodically restores it. However, it is now possible to cement line mains in place after the cleaning operation.

Data regarding the maintenance of the coefficient of carrying capacity of cement-lined pipe are not so plentiful as for tar-coated pipe. The Cast Iron Pipe Research Association endeavored to secure such data by testing 42 cement-lined cast-iron pipe lines in 12 cities, located principally in the active or tuberculating water areas. All but eight of these mains had been in service from 10 to 16 years. The Hazen-Williams coefficient varied from 131 to 153, indicating little if any loss in coefficient value. Had these mains been tar-coated, it is believed the coefficient would have approximated 110.

The failure to adopt this improved coating more generally would appear to result from the average water works man's opinion that cast-iron mains, with the usual tar coatings, can be used in hard water areas without deterioration in carrying capacity. It is believed, by and large, that is not the case. It is suggested that, prior to the beginning of any important expansion of a distribution system, comprehensive flow tests be run and the relation between years of service and the Hazen-Williams coefficient be determined. If the loss is at all material, consideration of cement lining is suggested.

Unaccounted-for Water

There has been a greatly increased interest in "unaccounted for water" in recent years. As recently as 15 years ago, the average completely metered, well administered water works accounted for less than 75 per cent of the water used. At the present time that percentage is about 85 per cent, with a very few cities exceeding 90 per cent. One city of approximately 150,000 people, which had been completely metered for 40 years, was accounting for but slightly more than 60 per cent of the water pumped. By careful attention to its meters, their repair and accuracy of registration at low flows particularly, the accounted for water in this system has now been brought up to 83 per cent. The utility is now being paid for 35 per cent more water than before the improved meter maintenance program was started. The principal change was to see that all meters would register the low flows.

It is believed that the most important factor in reducing the quantity of water unaccounted for is the careful maintenance and repair of meters, with particular emphasis placed upon the accuracy of registration at low flows. Instead of referring to 15 to 25 per cent unaccounted for water, it has been suggested by Mr. A. P. Kuranz, Supt. of Water at Waukesha, Wis., that the unaccounted for water be visualized in terms of the equivalent waste of two to three months' coal, power and chemicals each year. In Mr. Kuranz's plant he has reduced the unaccounted for water to less than 7 per cent, an illustration of what can be done.

Water waste control, however, requires more than attention to the meters. It includes the necessity of locating leaks promptly and repairing them immediately. Every facility must be used to locate the hidden leaks, such as watching for melted spots on the streets during periods of light snow and listening at meters, valves and hydrants when routine inspections are being made.

Hydrants

Hydrants should be inspected at least twice each year, at which times they should be operated and checked for the operation of the drip, free draining, condition of packing etc. They should also be carefully inspected after each use in the cold weather months. Each hydrant, too, should have a card on which should be recorded everything done to the hydrant, including each semi-annual inspection and what was observed at that time. Such a record is invaluable in case attempt is made to fix liability for a non-operative hydrant which may result from an attempt to open in the wrong direction, mishandling or some other cause.

It is good practice to install hydrants farther back from the curb and street corners than was formerly the practice before the use of the automobile became universal. It is also good practice to have a shut-off gate valve on every hydrant connection.

Hydrants should never be operated by other than the fire department or water works employees. The occasional use of fire hydrants to fill sprinkling wagons, and to flush sewers and streets, is bad practice. It jeopardizes the ability of the water system to function when most needed. In one city, where hydrant wrenches were too freely distributed, the annual cost of maintenance and repair was over $8 per hydrant as compared to an average of less than $3. The number of hydrants replaced, in proportion to those in use, was double that of other cities where the use of hydrants was properly restricted.

Valves

Valves should be inspected at regular intervals. If all valves do not open in the same direction, all exceptions should be recorded and their existence emphasized. Every valve should have a number and a card on which pertinent data relative to its location, installation, repair and maintenance are included. All valves should be provided with means of access, and it is good practice to install valves 12-in. and larger in vaults. Packing of valves should be inspected and adjusted when necessary.

Valves should be spaced at intervals of 500 to 800 ft. and so placed that no break will take more than two blocks of pipe out of service.

Distribution Maps

Too many water works either have no adequate map records or they are not kept up to date. A wall map should be available, of such scale as to make it usable. There should also be a sectional atlas of the entire pipe system on sheets about 24x36 in. and scale of 50 ft. or 100 ft. to the inch, with intersections and other congested areas enlarged when necessary.

RELATIVE SIZES OF BRANCHES AND WATER MAINS

Size of Main	Number and Size of Branches Main Will Supply—Running Full
½"	Two—⅜"
¾"	Two—½"
1"	Two—¾"
1¼"	Two—1" *or* One—1" and Two—¾"
1½"	Two—1¼" *or* One—1¼" and Two—¾"
2"	Two—1½" *or* One—1½" and Two—1¼"
2½"	Two—1½" and Two—1¼" *or* One—2" and Two—1¼"
3"	One—2½" and One—2" *or* Two—2" and Two—1½"
3½"	Two—2½" *or* One—3" and One—2" *or* Four—2"
4"	One—3½" and One—2¼" *or* Two—3" *or* Three—2½" and One—2" *or* Six—2"

FINANCING DISTRIBUTION SYSTEM EXTENSIONS*

by
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MANY methods and practices followed in the extension of distribution systems into new territory, many of which are not producing the income they should, require review and careful analysis to determine whether or not they are properly financed. It is quite conceivable that many extensions, although bringing in additional revenue, are, in fact, a financial burden on the system as a whole. Of course, some of the past methods cannot be changed overnight, as they are so securely fixed by custom, ordinance, or contract.

Equitable Rate Structure a Major Consideration

In considering this subject, there is one major factor to keep in mind—the rate structure or schedule. Almost every water works operator, whether his plant is publicly or privately owned, will find it most distasteful and difficult to revise the rate schedule of his property unless he is able to make the revision downward. It will be assumed, therefore, that it is the desire, and should be the responsibility, of every operator to approach the expansion of the water works system with an eye toward the preservation of the existing charges for water service. Precaution should also be taken to prevent the necessity of increasing the rates charged existing customers to help defray the costs of taking on new customers supplied by main extensions not properly financed.

Two factors must be considered in the proper financing of an extension: first, the revenue of the particular extension and the increase in operating expenses it will cause; and second, the additions to plant and property—such as services and meters—as well as the investment in pumps, filters, reservoirs and the like, that will be required to supply adequately the extension and the consumers taking water from it.

Calculating Probable Revenue

The calculation of the probable revenue from an extension can be approached from several angles. Rather than estimating the total revenue an extension may produce and working out the financing from this point, it is better and safer to eliminate as much guesswork as possible. There never is the certainty that all the lots will be built upon and, if built upon, that the units will be occupied. To reduce these uncertainties to a minimum, it is, therefore, best to work out the problem by giving consideration to the additional revenue as water customers become attached to the mains.

From the general character of the development and its location, as well as the size and design of the units, it is not too difficult to arrive at an average estimated revenue to be expected from each unit to be served by the extension. Such an estimate is, of course, based on the revenues being received from similar units already attached to the system.

The probable operating expenses of an extension—or rather the increase in the operating expenses of the property as a whole due to the addition of the new customers—cannot be properly approached by any method other than average costs. It would require an exhaustive study to find out by what increment each new customer would increase operating expenses, and if this increment were to be determined for each new customer it would naturally have to vary. Such an approach would also make it necessary to determine just which new customer required the hiring of an additional employee in the water works organization. As the development of this paper will show, the economies of an extension can be properly treated only on an overall basis and with a long-term view.

Average costs can best be expressed by giving consideration and weight to the operating ratio, the percentage of the gross operating earnings expended for operation and maintenance. Deducting this figure from the gross operating earnings gives the return—that is the amount available to meet the costs of borrowed capital and to provide a profit. Operating ratios are not the same for all properties as each has its own particular problem, affecting in one way or another the relationship between revenues and expenses. The operating ratio of a single property will, however, remain fairly constant from year to year, moving in one direction or the other rather slowly. To determine the operating ratio of a property for use in calculating the earnings of an extension, it would be well to figure it out for a number of years in order to eliminate any years during which some unusual event occurred and materially disturbed the operating ratio for that year.

Example

To take an example, it may be assumed that the estimated gross revenues from the extension under consideration average $15.00 a unit and that the operating ratio of the water works property which is making the extension is 40 per cent. The return from each unit, disregarding other matters, will, therefore, be $15.00 minus $6.00 (40 per cent of 15), which leaves $9.00. This $9.00 is the amount of money that will be available from each unit to support the investment in the pipelines, service lines, meters and other materials making up the extension as well as other additions to the plant as a whole.

Investment Required in Other Facilities

It is at this point that the greatest tendency exists for making errors and omissions in the proper financing of distribution system extensions. Small properties which have no prospects of further growth and at the same time have ample supply facilities can assume that a reasonable return on the investment in the extension alone is sufficient. Should it develop, however, that the property needed some expansion of its supply, the earnings of the property under existing rates would not be sufficient to support an investment in additional supply facilities, which, by their very nature, are not revenue producers. In determining the proper financing arrangement for distribution system extensions, consideration must also be given to the required investment in other plant facilities.

Admittedly, additional investments in plant facilities, other than pipelines, are not in the same category as the investments made in pipelines. Plant facilities are added in larger steps and at uneven rates. In a property's history there will be times when the supply facilities are more than adequate and times when they should be enlarged.

However, assuming that the development of plant facilities has been kept reasonably abreast of the growth of the distribution system, and records have been accurately maintained, the ratio of the total cost of, or investment in, pipelines alone to the total investment will provide a very useful figure in determining what the proper return on a pipeline extension should be. This ratio is arrived at by dividing the total cost or investment in pipelines, fire hydrants and fire hydrant branches by the total plant value. The figure should not vary much from year to year in the future, as it is based on total values over a long period and yearly variations will be small by comparison.

Apportioning the Investment

Assuming that the investment in pipelines alone of the water works property mentioned above is 45 per cent of the total value of the plant, for every $45 invested in pipelines another $55 will eventually have to be expended for all other facilities needed to render service to customers on the extension under consideration. Put in another way, this means that, at the particular imaginary plant, for every $1.00 invested in water mains, fire hydrants and hydrant branches $1.22 will have to be spent on other facilities.

It was found previously that of the $15.00 of estimated revenue for each unit, $6.00 would be spent on operating expenses, leaving $9.00 available to support the investment in the facilities needed to supply each unit. For the purposes of this paper, a return of 6 per cent on the value of the property will be assumed sufficient to cover the overall costs of borrowed money and a reasonable profit. The $9.00 using the figure of 6 per cent will therefore support an investment of $150. This $150, unfortunately, is not the amount of money that can be prudently spent on pipelines for each of the $15.00 customers expected on the extension under consideration. To take care of the cost of other facilities to supply each of these new customers, only 45 per cent of the $150, or $67.50, can be invested in water mains. The remainder, $82.50, will have to be spent on other facilities, such as meters, services, pumps and filters, if the existing relationship of the cost of mains to the total value of property holds true.

If the need for investment in all possible facilities other than mains is neglected when arriving at the return an extension should yield, it will become necessary to increase water rates at some future time. If all the revenue available from an extension is used to support the investment in pipelines alone, there will not be any cushion of revenue to support the investment in other needed facilities, such as added filter and pumping capacity. Furthermore, should it be found necessary to increase rates to support the cost of added facilities because of such omission, the increased rates would be imposed on the old customers for whom the additional facilities were not needed, as well as on the new customers.

Calculating Return Necessary

With an operating ratio of 40 per cent, a figure of 45 per cent representing the ratio of the value of pipelines to the total value

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of the plant and 6 per cent as a fair return, $15.00 of revenue could support an investment of $67.50 in pipelines. This represents a gross return of 22.2 per cent, calculated by dividing $67.50 into $15.00. The dollar figures can be eliminated and, using only the three percentages, the same 22.2 per cent can be arrived at thus:

$$\frac{0.06}{0.60 \times 0.45} = \frac{1}{4.5} = 0.222 = 22.2\%$$

The 22.2 per cent figure means that a water works property operating under the above conditions must earn 22.2 per cent of the cost of a pipeline extension to pay the increased operating expenses and receive a return of 6 per cent on the cost of the extension and the cost of other necessary additions to its supply facilities used in rendering service to the extension customers.

As mentioned before, probably no two water works properties have exactly the same operating ratio or relationship between the total value of pipe and the total value of plant. However, assuming that records have been kept so that it is possible to determine what these two percentage figures are, and that the desired return has been established, the same calculations as above can be made to determine what the gross yield on a pipeline extension should be, expressed as a percentage of the cost of the extension.

Assuring the Proper Return

When it is apparent that a pipeline extension will not yield the desired gross return on the cost of pipeline installation alone, it is quite essential that some arrangement be agreed on so that the water property will be assured of the proper return.

One way would be to work out with the developer, or a representative of the customers to be served by the extension, an agreement by which the water property would be guaranteed the required return (22 per cent in the example used). The water utility would then keep an account of the revenue collected on the extension each year and calculate what percentage of the cost of the extension this revenue represented. The guarantor would then make up the difference between the percentage found and the guaranteed amount, until such time as the actual annual revenue collected equalled or exceeded the required amount.

This type of contract does not have much appeal to a developer or an individual, because of its continuing nature. Furthermore, it would not be of much value to the utility unless the credit of the guarantor were well established. The most satisfactory arrangement from the utility's point of view, and also from the developer's, is to have the entire cost of the pipeline extension placed on deposit with the utility. The utility then has the money and the developer has some definite figure to work with for the determination of his costs of development.

Since the utility can calculate what its gross return on an extension should be, it ought to be willing to refund to the depositor sums of money which would be representative of the amount the utility can afford to invest for the revenue produced by the new customers added to the extension. Using the same gross return of 22.2 per cent and the estimated revenue of $15.00 previously assumed for each unit on the extension, the utility can afford to refund, for each unit added to the extension, a sum equivalent to $15.00 divided by the desired gross return of 22.2 per cent, or $67.50. This should be recognized as the same figure previously arrived at.

Expressed in another way, using the reciprocal of 0.222 which is 4.5, and multiplying: $4.5 \times \$15.00 = \$67.50$. This reciprocal can be used to express briefly what the utility can invest in pipeline extensions; namely, 4½ times the estimated revenue.

This factor of 4½ would not hold true for all properties, but a similar figure can be developed for any given utility.

PIPE FLOW CHART

By simply laying a straightedge across this chart any one of these questions may be answered:

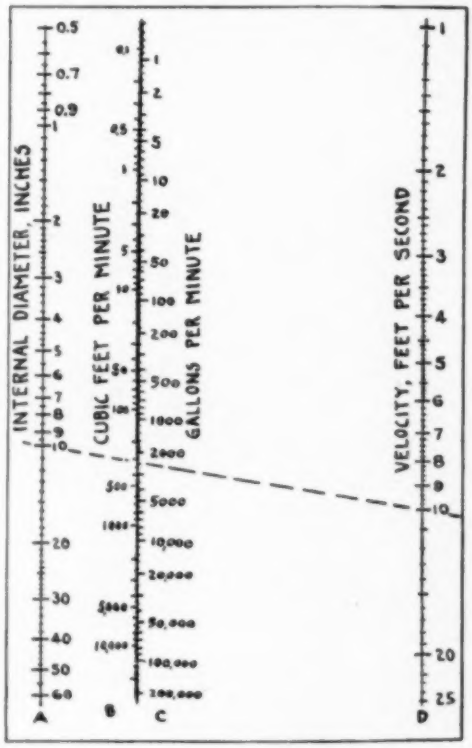
1. How many cubic feet will flow through a pipe of given diameter at a given velocity?
2. How many gallons, other conditions being the same as in No. 1.
3. What will be the velocity in feet per second, knowing the diameter and cubic feet per minute?
4. Same as (3) except that the flow is given in gallons per minute.
5. What diameter of pipe must be used to carry a given number of cubic feet per minute at a given velocity?
6. Same as (5) except that quantity is in gallons per minute.

For example, how many gallons of water per minute will flow from a 10 inch pipe line if the velocity reaches 10 ft. per second?

The dotted line drawn across the chart shows that if the internal diameter of the pipe is 10 inches (col. A), and the water is flowing at a velocity of 10 ft. per second (col. D), the amount of water flowing is a hair less than 2,500 gal. per minute (col. C), which is equivalent to about 325 cubic feet per minute (col. B).

Naturally the chart may be used to obtain the pipe diameter needed to avoid exceeding a given velocity at a given rate of flow. It may also be used for converting gallons to cubic feet and the reverse.

Contributed by W. F. Schaphorst, M.E., Newark, N. J.



WATER WASTE SURVEYS AND LEAKAGE CORRECTION*

With Particular Reference to the Pitometer and Its Use in Making Such Surveys

By E. SHAW COLE

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IT HAS been suggested that a pitometer survey be compared with a complete medical and physical examination such as would be made in a clinic. Various measurements would be made to determine the physical condition of the patient. The type of tests, the equipment and the technic have all been improved over the years, and, while these have probably resulted in better diagnosis, the basic tests have not been changed greatly. So it has been with the pitometer survey. Years ago the pitometer was called the x-ray of water works systems. Although new tools have been provided and technics improved to increase the efficiency of the survey, the basic flow measurements developed years ago are still important and valuable.

To carry the medical analogy one step further, let us consider that the counterpart of the general practitioner or family doctor is the water works superintendent or local engineer. While these men do splendid work and in some cases operate for years without any outside help or advice, it is quite common for a progressive doctor to send a patient to a clinic for a complete physical and medical examination. At the clinic are to be found doctors trained in this type of work—men who specialize in a particular field and for this reason excel in it. The need for an organization of engineers which specializes in conducting pitometer surveys and can be called on at any time to help in whatever way is desired, whether it be for a short test or a complete survey, is somewhat similar to the need for clinics. Perhaps this need is best illustrated by the fact that during the last five years, the author's firm has conducted a total of 251 surveys and tests in 159 different communities. The majority of these were water waste surveys that covered approximately 12,000 mi. of mains. This work resulted in the location and repair of over 6,500 hidden underground leaks wasting a total of 106 mgd. At an average purchase or production cost of five cents per 1,000 gal., this amount of water represents an annual saving of $1,935,000.

While the judgment of federal agencies is not necessarily the best criterion, it is interesting to note that the 251 surveys and tests included work for four large Navy shipyards, as well as for several cities where the FWA thought it sound practice to have a survey made before approving grants for expensive extensions and reinforcements. The federal government of one of our neighboring countries also authorized a pitometer survey in one of its cities, as the quickest and most economical means of obtaining an adequate supply for one of its largest arsenals. Also included are tests for important war plants, including a government arsenal, airplane manufacturing plants and oil refineries.

Scope of Pitometer Surveys

The pitometer survey is an engineering operation divided into two definite fields:

1. An accounting for all the water delivered to the distribution system, known as the water waste survey.
2. An engineering study of the existing distribution system to improve distribution facilities.

While the primary object of the pitometer water waste survey is to locate underground leakage, its scope is very much broader than this. The operations may be divided as follows:

1. Test of pumps for slip or efficiency.
2. Measurement of the flows at either end of gravity supply lines to determine leakage.
3. Measurement of the flow in and out of reservoirs to determine leakage.
4. Test of master meters for accuracy.
5. Measurement of the flow to various districts of the city. A study of the night rate of flow and its relation to the total, indicates the existence of leakage. Also, the information obtained is the basis for future design and extensions and replacements in a distribution system.
6. A test of large industrial meters and a check on industries for unauthorized use of water.
7. Night subdivision, or the analysis of the night rate of flow in districts where waste is indicated, which result in the measurement of the flow in every block or between every set of valves.
8. Location of underground leakage. By this method of night subdivision, every underground leak in the system large enough to justify the cost of repair is indicated by measurement and its exact location determined by the use of sound intensifiers.
9. House-to-house inspections, based on the result of night subdivision, are carried out for the purpose of controlling leaking plumbing fixtures in unmetered systems. In metered systems, the measurements provide indications of under-registration of domestic meters.
10. Special tests that include such things as river-crossing tests, industrial tests and measurements not mentioned above.

Not all surveys result in spectacular findings in each of these steps but the following examples are not unusual, and some of them have been encountered in otherwise well-operated systems.

Pump Tests

The logical starting point of any engineering project of this kind is the source of supply. In the early days where the supply was pumped, a test to determine the slip of the reciprocating pumps frequently showed amazing conditions. In some cases where maintenance was entirely absent, slip ran as high as 80 to 90 per cent, as could be demonstrated by shutting the discharge valves practically to the closed position without raising the discharge pressure.

As reciprocating pumps have been replaced by centrifugal pumps, the pump tests have come to include wire-to-water efficiency tests. These, too, sometimes show surprising conditions, as described in an excellent paper by H. E. Beckwith, entitled, "A Simple Method of Testing Centrifugal Pumps" (*Jour. A.W.W.A.*, 31: 2098 (1939)). According to Beckwith, it is not unusual to find a centrifugal pump which is operating under an entirely different set of conditions than that for which it was designed. He cites a test that gave a wire-to-water efficiency of only 40 per cent. The savings resulting from the installation of a pump designed to meet the operating conditions were very substantial.

Supply Lines

In gravity systems, the starting point for the survey is the reservoir and the gravity supply lines it feeds. A test of the gravity supply lines is made by measuring the flow at the inlet and at the outlet and, at the same time, leakage from the reservoir is determined by measuring the rise and fall in the reservoir, adjusted for the flow in or out, as the case may be. Where a long gravity supply line crosses rough and marshy country and possibly a river, it is important to know by direct measurement that there is no appreciable underground leakage.

The approximation of accuracy by any hydraulic instrument in the field is not much greater than 100 ± 2 per cent. In large gravity lines, a small loss could go undetected, due to the allowable error of the measurements. At the same time it should be pointed out that many losses have been detected where the difference between the inlet and outlet quantities did not exceed 3 to 4 per cent. In a survey for a small New Jersey system, a measurement of the flow in each end of a gravity line, 7 mi. long, showed discrepancies of 30 per cent between the reservoir and the town. The demands of this system had gradually increased over a period of years until it became necessary to install a booster pump in order to maintain an adequate supply. After the original discrepancy had been detected, intermediate gagings were made to localize the section where the loss occurred. Sound intensifiers were then used with positive assurance that leakage existed and a blown joint, which was wasting 250,000 gpd. into a large swamp, was quickly discovered.

Master Meter Tests

The testing of master meters for accuracy is a routine step that is necessary if figures on unaccounted-for water are to be used as the criterion for efficient operation and the absence of lost water. In the case where water is purchased through a master meter this test has a real dollar value and in two New Jersey communities substantial savings resulted from the discovery that the meters were over-registering. In one case there was an overcharge of 16 per cent. In the other instance, it was

*From the *Jour. AWWA*, 37, 181-188 (1945).

found that the flow through the master meters reversed during the night hours. Because the type of meter used registered positively, regardless of the direction of flow, this community was charged twice for water that was never used—once when it entered the system and again when it left it.

District Measurements

The division of a system into districts and the measurement of the flow into each district for a period of at least 24 hours provides information that is not only of value in indicating the existence of underground leakage, but gives valuable information regarding the operation of the entire distribution system. Primarily the district measurements are made so that the night rates of flow may be studied. The actual size of the district will vary but usually includes from 8 to 10 mi. of main and may be as large as 30 mi. A high flow at night of over 30 per cent of the total in the residential section of a metered system indicates the possibility of leakage and justifies further investigations, while a 40 per cent night rate is a sure indication of leakage or waste of some kind. A low ratio of night flow to the total flow, however, indicates that it would be uneconomical to make further investigations.

In cities where more than one survey has been made, a comparison with results of the previous district measurements provides a more exact means for predicting the existence of leakage. Some of our larger cities, notably Philadelphia, Pittsburgh, Rochester, Boston and Cincinnati, have found it economical to have a certain amount of work done each year, so as to keep their waste down to a minimum.

The district measurements are an important part of these annual surveys, for in this way it is possible to cover a large number of miles quickly by eliminating the many sections that are invariably found to be tight, and then to concentrate detailed investigations in areas that are definitely known to contain waste or leakage. In this connection it should be noted that the over-all accounted-for figures in large systems, where the consumption may be 30 to 40 mgd. or greater, are subject to so many variables with regard to consumption that it is not as easy to detect the presence of underground leakage as it is in a small compact system. A change of only a small percentage in a large system can involve more water than the entire consumption of the small system.

By isolating the districts by means of closed valves, so that the feed may be supplied through one or more large mains on which the pitometer is installed, it is possible to learn a good deal about the operation of the trunk mains. Pressures are taken before and after the district is isolated. The flows are studied and the adequacy of existing feeds taken into consideration, so that in case of fire there will be ample supply until the key boundary valves are opened in accordance with arrangements made between the fire and the water departments.

In one survey the formation of the district boundaries proved to be a difficult operation, due primarily to the condition of the valves and errors in the map. The time involved in solving the problem, however, proved to be well worth-while for the city because two of its important feeders were found to be carrying no water. Investigation showed that one 12-in. valve was closed, one double-check valve was frozen closed and one 12-in. valve was partly closed. The latter discovery explained the reason for inadequate pressures during a recent fire.

In another system there was a high area that had suffered from low pressures for years. When district measurements were being made at the start of a survey it was found that the principal feed, a 20-in. main, carried no water because of a 20-in. valve that was closed and too stiff to operate.

In addition to these not infrequent discoveries, district measurements always provide information regarding the consumption in the various sections of the system that are of value as a basis for designing extensions or reinforcements to the distribution system.

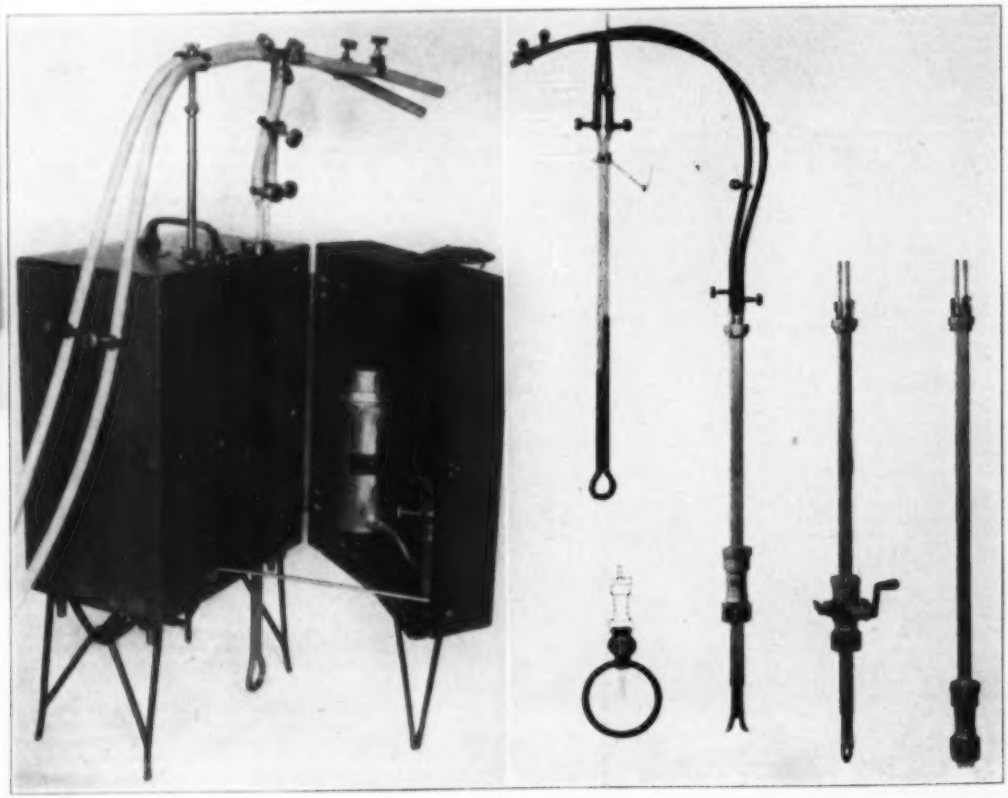


Photo Recorder — *Equipment Used in Pitometer Survey* — *Pitometer Rods and Manometer*

Industrial Meter Tests

Improved meter practice and close supervision of industria consumers has greatly reduced the loss of water in many systems, but there are still a large number of meter departments which do not make complete checks on the accuracy of the large meters and the use of water passing through them and through fire lines.

The advantages of testing large meters in place and under operating conditions, with the pitometer, may not be apparent to those meter superintendents who periodically use a test meter to check their meters. While it is true that there are some systems where the meters are in excellent condition, within three weeks two cases of under-registration involving large quantities of water were brought to light during routine field tests. In one large eastern city, a fire line meter was tested in spite of the fact that it showed no registration and that the factory said they were not using any water through it. The test showed that there not only was a flow but it was so large that a continuous test was run for a week. The average under-registration for this period was 427,000 gpd. and the rate varied from zero to maximum of 1,660,000 gpd. through a 6-in. pipe, or a velocity of over 13 fps. Four hundred and twenty-seven thousand gallons per day is not only a lot of lost water, but at a meter rate of ten cents per 1,000 gal. the lost revenue amounts to over $15,000 a year.

Night Subdivision and Leak Location

Following the 24-hour district measurement comes the problem of locating all underground leakage. Indirect gaugings are made to determine the distribution of the night rate of flow. These gaugings are made after midnight and before five o'clock in the morning. All mains, regardless of how small they may be, are included in these measurements and the unit of test is as small as it is practicable to make it with the valves available. Manifestly, if there is no flow into a piece of pipe after midnight there can be no leakage. Where an appreciable flow is shown to exist, further investigations are made to determine the cause. The importance of these measurements cannot be over-emphasized, because only in this way is there a *positive* indication of the existence of underground leakage.

The location of leaks has been a common occurrence in every water works since the first leak patrols were organized in England over 100 years ago and perhaps long before that. The main point to be emphasized here is the difference between the leak patrol or listening type of survey and the pitometer survey. By the periodic use of sound intensifiers leakage can be and is controlled by almost every water works plant. This type of control is excellent practice and should be encouraged. At the same time it should be recognized that this method is in a sense a negative control, *i.e.*, if no noise is heard on a main or its connections, it is concluded that there is no leakage; or if a slight noise is heard, and further investigation does not result in the discovery of a leak, it is concluded that the leak is too small to bother with, which may not be the case. Experience indicates that the intensity of sound does not necessarily indicate the volume or size of a leak.

An actual measurement of the flow between a set of valves when use is at a minimum, or is a known quantity, is a *positive* approach. Only after a water measurement is made can it positively be said that leakage does or does not exist, and, if there is leakage, only by a water measurement can the amount be determined. In the pitometer survey it is at this point that sound intensifiers are first used. Then with a definite knowledge of the size and approximate location of the loss, investigations are made with whatever type intensifier the engineer prefers, until all leakage of sufficient importance to warrant repair is located.

The record is full of instances where the sound indications were so misleading or faint that large leaks had existed for years. Take, for example, interfering noises from pumps, motors, regulating valves, machinery, etc., or the case of a deep fill, a river-crossing or an abandoned service.

In this connection it is worth noting that the quantity of leakage located, rather than the number of leaks, is the important consideration to a community. For example, a survey was made in a metered New England city having a domestic per capita consumption to 64 gpd. Only a handful of small service leaks were found in the distribution system proper, but because the survey was a complete audit, a measurement was made on a pumping line leading to a reservoir some distance out of the city. This main crossed some rough and swampy ground and there were no connections to it. The function of the pump station was to augment the main gravity supply to the reservoir and whenever the water level dropped to a certain point the pump started and ran until the reservoir was filled. The measurement on this main showed a loss between the pump station and reservoir of 430,000 gpd. and further investigation resulted in the discovery of a leak wasting 250,000 gpd. into the swamp, when the pump was off, and 390,000 gpd. when it was operating and the pressure thus increased. This one leak was largely responsible for the need of pumping, as it was continuously draining the reservoir. The savings in pumping costs alone amounted to $4.50 per day at one cent per kilowatt hour.

At the other extreme, is the case of a large unmetered gravity system where leakage and waste were rampant because there was an abundant supply. Unfortunately, the capacity of the 7-mi. transmission mains was limited and shortly before the war the demand had increased to the point where pressure troubles developed and it was necessary to curtail service in order to get water into the large distribution reservoir. Then with the war came a large arsenal that demanded 10 per cent of the total consumption. This additional amount could not be supplied and so the government authorized a complete pitometer survey as the quickest and most economical approach to obtaining an additional supply. Here the resultant action could be called selective leak location. Only the large leaks were dug up and repaired at first so as to reduce consumption as rapidly as possible, and in this case measurements were invaluable. Hydrant leaks making a terrific roar were encountered on almost every other corner, and yet broken mains, part of the time submerged by the tidal river, made no noise at all on the surface of the street due to the nature of the ground conditions and undermined pavements. Within six weeks, leaks releasing over 4 mgd. had been repaired and at the completion of the survey leaks totaling 13 mgd. had been located.

Other Benefits of Subdivision Studies

In addition to providing positive information regarding leakage, the night subdivision measurements have several other valuable features. During the course of the measurements, it is necessary to close a large majority of the valves in the distribution system and prove their condition by making tight shutouts. Periodic inspections and operation of all valves in a distribution system is generally considered good practice. Usually, however, shut-outs are not made during the inspection, the main object being to see that the valve is free and in good condition. When a survey is made the night valve operations can take the place of the annual inspections. Many systems do not follow a valve maintenance program at all and in these cases the operations made during the survey are useful, not only as a check on the condition of the valves, but also on the distribution system map and records. One of the most interesting discoveries resulting from valve operations occurred in a southern city where it was found that a great many of the mains were not connected at intersections. This, it was said, came about as a result of street grading after part of the system had been installed, thus increasing the cover. When the gridiron was completed, no effort was made to connect mains that were at different depths. Only by methodically proving how the water was circulating were all these missing connections located, and the improvements in the strength of the distribution system after connections were made can be readily appreciated.

House Waste

The only sure way to eliminate unnecessary waste on the consumer's property is by universal metering. There are, however, many communities where universal metering is impractical for financial or political reasons, and in these communities only the largest consumers are metered.

The only other method of controlling this waste is by periodic house-to-house inspections and these are most efficiently supervised when the amount of water being wasted is first determined by night measurements. Following these, concentrated work in those sections found to have a large night consumption will produce the best results.

The benefits from these inspections are only temporary unless repeated at regular intervals and even then have no control over willful waste. However, a pitometer survey will indicate the most wasteful sections and several cities have adopted ordinances authorizing the water department to install meters when reinspections show that the consumer is a chronic waster of water and will not keep his fixtures in repair.

Distribution Studies

A second type of survey, the distribution study, has an objective somewhat different from the waste survey. Basic data accumulated through loss-of-head tests, fire flow tests, pressure and hydraulic grade line studies and computations are all dependent on a variety of flow measurements and gagings. The pitometer distribution survey is of value in determining the true physical condition of a distribution system before designing improvements.

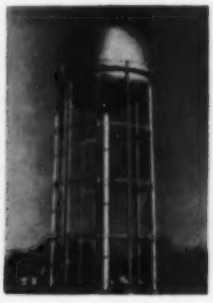
Whether the problem be the location of points of waste or the proper method of extending or improving the distribution system, the pitometer survey will be found to be a most valuable method of finding the proper solution.

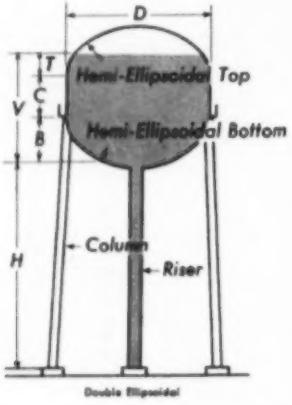
Capacities and Sizes of

STANDARD ELEVATED STEEL TANKS

by PITTSBURGH · DES MOINES

In these compact but complete tables, data are furnished on the various types of elevated steel tanks, and on steel reservoirs. For full information as to the application of these tanks, for designs, for specifications, or for estimates, write—without obligation to our nearest office.





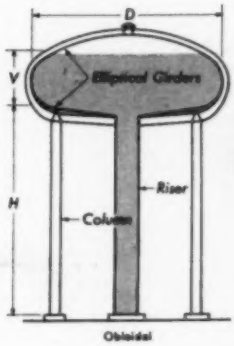
Double Ellipsoidal

TABLE I—DOUBLE ELLIPSOIDAL TANKS

Capacity U.S. Gallons	Tank Dimensions D	V	B	C	T	Balcony Width	Number of Columns	Radial Bevel of Columns	Tower Height H
25,000	18'0"	14'4⅛"	4'9"	6'0¼"	3'7⅛"	24"	4	1:12	see note**
30,000	18'0"	17'0"	4'9"	8'7¾"	3'7¼"	"	"	"	"
40,000	20'0"	18'6⅛"	5'2⅜"	9'4⅛"	4'0"	"	"	"	"
50,000	22'0"	19'2½"	5'11"	8'10⅜"	4'4⅜"	"	"	"	"
50,000	24'0"	16'8½"	6'4⅛"	5'6⅜"	4'9⅜"	"	"	"	"
60,000	24'0"	19'7½"	6'4⅛"	8'5⅜"	4'9⅜"	"	"	"	"
75,000	26'0"	21'2⅛"	6'10½"	9'1¼"	5'2⅜"	"	"	"	"
100,000	28'0"	23'8⅜"	8'7"	9'6½"	5'7¼"	"	"	"	"
100,000	30'0"	21'0⅞"	8'11"	6'1⅜"	6'0"	"	"	"	"
150,000	32'0"	27'4"	9'4⅛"	11'7"	6'4⅜"	"	"	"	"
150,000	34'0"	24'9⅜"	9'10½"	8'1⅜"	6'9⅜"	"	"	"	"
200,000	36'0"	29'4½"	10'6⅛"	11'8"	7'2⅜"	"	"	"	"
250,000	38'0"	33'0"	11'3⅜"	14'3⅛"	7'4⅜"	30"	6	1:20	"
250,000	40'0"	30'10½"	11'10½"	8'6"	10'6"	"	"	"	"
300,000	44'0"	30'9"	13'0½"	7'11⅜"	9'8⅜"	"	"	"	"
400,000	48'0"	34'3⅜"	14'7"	11'0"	8'8⅜"	"	"	"	"
500,000	50'0"	39'0⅜"	15'6⅜"	15'5⅜"	8'0⅜"	"	8	"	"
500,000	55'0"	29'11"	12'0"	10'11"	7'0"	"	"	Vertical*	"
600,000	50'0"	45'10½"	15'6⅜"	22'3⅛"	8'0⅜"	"	"	1:20	"
750,000	60'0"	41'7⅜"	18'0"	11'10⅜"	11'9"	"	"	Vertical*	"
750,000	65'0"	37'0⅜"	20'1⅜"	6'5"	10'5½"	"	"	"	"
1,000,000	63'0"	47'1⅛"	20'1⅜"	16'5⅜"	10'5½"	"	10	"	"
1,000,000	70'0"	42'6½"	23'0"	10'9½"	8'9"	"	"	"	"
1,000,000	75'0"	35'0"	20'6"	8'6"	6'0"	"	"	"	"
1,250,000	70'0"	51'2⅛"	23'0"	19'5⅜"	8'9"	"	12	"	"
1,500,000	70'0"	59'10⅛"	23'0"	28'1⅜"	8'9"	"	"	"	"

* Standard practice is to make columns vertical for Double Ellipsoidal Tanks whose diameter exceeds 50 ft. However, their columns may be inclined if desired, in which case their radial bevel would be 1:20.

** Standard tower heights (H) are as follows:
Up to 50 ft. in even 2 ft. intervals,
from 50 ft. to 100 ft. in even 5 ft. intervals,
and over 100 ft. in even 10 ft. intervals.
Most common standard tower heights are 73 ft. and 100 ft.



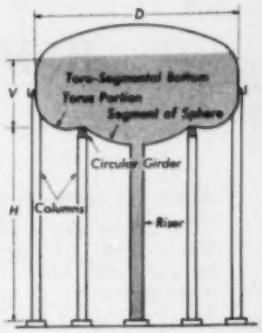
Obloidal

TABLE II—OBLOIDAL TANKS

CAPACITY U.S. GALLONS	DIAMETER D	HEAD RANGE V	TOWER HEIGHT H
1,000,000	88' 0"	25' 0"	As Required
1,500,000	92' 0"	35' 0"	" "
2,000,000	106' 0"	35' 0"	" "

TABLE III—TORO-SEGMENTAL BOTTOM TANKS

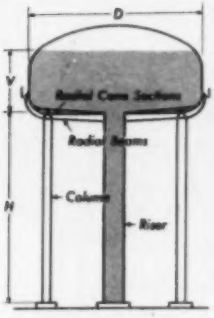
CAPACITY U.S. GALLONS	STANDARD HEAD RANGES V			TOWER HEIGHT H
750,000	25' 0"	30' 0"	35' 0"	As Required
1,000,000	25' 0"	30' 0"	35' 0"	" "
1,500,000	25' 0"	30' 0"	35' 0"	" "
2,000,000		30' 0"	35' 0"	" "
2,500,000		30' 0"	35' 0"	" "
3,000,000		30' 0"	35' 0"	" "



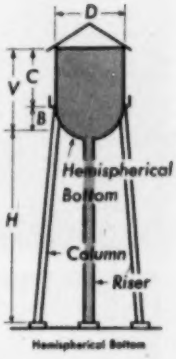
Toro-Segmental

TABLE IV—RADIAL CONE BOTTOM TANKS

CAPACITY U.S. GALLONS	TANK DIMENSIONS D	V	NUMBER OF COLUMNS	TOWER HEIGHT H
300,000	53' 0"	20' 0"	8	As Required
500,000	60' 0"	25' 0"	"	" "
750,000	73' 0"	25' 0"	"	" "
750,000	67' 0"	30' 0"	"	" "
1,000,000	85' 0"	25' 0"	10	" "
1,000,000	77' 0"	30' 0"	"	" "
1,000,000	71' 0"	35' 0"	"	" "
1,250,000	95' 0"	25' 0"	12	" "
1,250,000	87' 0"	30' 0"	"	" "
1,250,000	80' 0"	35' 0"	"	" "
1,250,000	74' 0"	40' 0"	"	" "
1,500,000	103' 6"	25' 0"	"	" "
1,500,000	95' 0"	30' 0"	"	" "
1,500,000	88' 0"	35' 0"	"	" "
1,500,000	81' 6"	40' 0"	"	" "
2,000,000	108' 6"	30' 0"	16	" "
2,000,000	101' 0"	35' 0"	"	" "
2,000,000	94' 0"	40' 0"	"	" "
2,500,000	121' 6"	30' 0"	"	" "
2,500,000	112' 0"	35' 0"	"	" "
2,500,000	105' 0"	40' 0"	"	" "
3,000,000	123' 6"	35' 0"	20	" "



Radial Cone



Hemispherical Bottom

TABLE V—HEMISPHERICAL BOTTOM TANKS

Capacity in U.S. Gallons	Tank Dimensions D	V	B	C*	No.** of Columns	Balcony Width	Tower height from foundation top level to bottom capacity level of tank (H)††						
5,000	9'0"	11' 0⅛"	1'2½"†	9' 9⅛"	4	None	31' 9"	38'3"	51'9"	58'9"	72'9"	79'9"	93' 9"	100' 9"
10,000	13'0"	11' 7⅛"	6'0"	5' 7⅛"	4	None	30' 0"	40'0"	50'0"	60'0"	70'0"	80'0"	90' 0"	100' 0"
15,000	13'0"	16'10⅛"	6'0"	10'10⅛"	4	None	30' 0"	40'0"	50'0"	60'0"	70'0"	80'0"	90' 0"	100' 0"
20,000	13'0"	21' 8"	6'0"	15' 8"	4	None	30' 0"	40'0"	50'0"	60'0"	70'0"	80'0"	90' 0"	100' 0"
25,000	13'0"	19'10½"	5'4"	14' 6½"	4	18"	44' 8"	50'0"	69'8"	75'0"	94'8"	100'0"	125' 0"	
30,000	13'0"	23' 8¼"	5'4"	18' 4¼"	4	18"	44' 8"	50'0"	69'8"	75'0"	94'8"	100'0"	125' 0"	
40,000	17'0"	24'11¼"	6'8"	18' 3¼"	4	24"	46' 3"			75'0"	96'3"	100'0"	123' 0"	
50,000	19'0"	25' 6"	8'0"	17' 6"	4	24"	55' 0"	63'4"	75'0"	83'4"	91'8"	100'0"	120' 0"	140' 0"
60,000	19'0"	30' 3½"	8'0"	22' 3½"	4	24"	55' 0"	63'4"	75'0"	83'4"	91'8"	100'0"	120' 0"	140' 0"
75,000	21'0"	30' 6¾"	8'0"	22' 6¾"	4	24"	55' 0"	63'4"	75'0"	83'4"	91'8"	100'0"	120' 0"	140' 0"
100,000	24'0"	30'11⅜"	8'6"	22' 5⅜"	4	24"	50' 0"	63'1"	75'0"	79'7"	91'6"	100'0"	116' 6"	141' 6"
150,000	28'0"	34' 5⅞"	10'5"	24' 0⅞"	4	30"	54'10"	63'2"	75'0"	83'4"	91'8"	100'0"	120' 2"	140' 3"
200,000	32'0"	35'11½"	12'9"	23' 2½"	6	24"	54' 1"	62'5"	75'0"	83'4"	91'8"	100'0"	120'11"	141'10"

* This column lists height of tank cylinder up to high water level. The cylinder actually extends 3" higher.
† The bottom of this 5000 gallon tank is a segment of a 9 ft. radius sphere.
** Radial bevel of columns of 4 column towers is 1-11/16:12, of 6 column towers 1:10.
†† Towers of heights other than those listed are available.

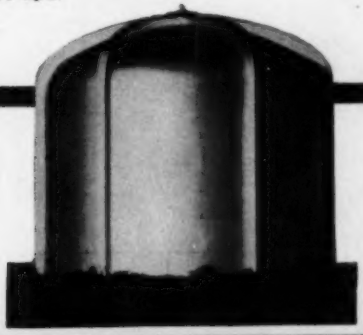


TABLE VI—STEEL RESERVOIRS

Capacity in U. S. Gallons	Diameter	Height
50,000	20'	21' 6"
60,000	22'	21' 6"
75,000	24'	22' 6"
100,000	26'	25' 6"
150,000	30'	28' 9"
200,000	34'	29' 9"
250,000	38'	29' 9"
300,000	42'	29' 3"
400,000	46'	32' 6"
500,000	50'	34' 6"
750,000	60'	35' 9"
1,000,000	70'	35' 0"
1,500,000	80'	40' 3"
2,000,000	95'	38' 3"
2,500,000	110'	35' 6"
3,000,000	120'	35' 9"
4,000,000	130'	40' 9"

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STORAGE ON THE DISTRIBUTION SYSTEM*

BY CHARLES B. BURDICK

Cons. Engr., Alvord, Burdick & Howson
Chicago, Ill.

IT HAS been aptly said that elevated storage is like money in the bank. It represents work already accomplished and an asset that can be drawn upon for instant use when needed.

Unlike storage on any other part of the water works system, storage on the distribution system is actually beneficial to every part of the water works, extending all the way back to the source of supply through feeder pipes, pumps, treatment facilities and, in many cases, the water development facilities.

Like money in the bank, wherein only a certain amount is necessary for day to day commercial transactions, enough is enough. Money invested in excessive storage would better be devoted to something more needed. It is the present purpose to show how much storage may be warranted under general conditions and the available means for accomplishing it, bearing in mind that no two cases are exactly alike and that while the conditions surrounding most water works are similar, there are wide variations in conditions affecting certain cases. Therefore each case should have separate study if the project is to be both technically and economically sound.

Generally speaking, that water works system is the best that provides facilities adequate to meet all conditions of service, including rare emergencies, at the least cost. The latter takes into consideration expenses of operation balanced against capital costs, usually represented by interest and depreciation upon the investment.

Storage upon the distribution system is of principal value in the form of adequacy and reliability of service, and in its economy. It is justified to the extent that it increases more constancy of pressures and greater reliability and economy, bearing in mind that in practically all installations allowance must be made for the probable service requirements for a reasonable period in the future. Both reliability and economy are promoted by the effects of storage in securing more economical pumpage, and in providing an assured pressure and adequate volume of water for fire protection.

*A basic discussion of this important topic prepared especially for the Reference and Data Number of *Water & Sewage Works* at our request.—The Editors.

Conditions Affecting Storage

Every water works man would have his problem much simplified, and the investment in water works would be much reduced, if water could be served at a uniform rate of delivery throughout the year. This is impossible, however. The consumer properly demands water when he needs it, and needs vary widely with the seasonal extremes and wide variations in demand throughout the hours of the day.

Storage is particularly beneficial in the afternoon or evening hours upon a few days in exceptionally hot and dry summers. Such summers do not come every year, and therefore excessive demand often comes as a surprise. An examination of many pumping records indicates that the demands of one summer in five or ten may greatly exceed the ordinary summer. Therefore, in providing facilities for storage it

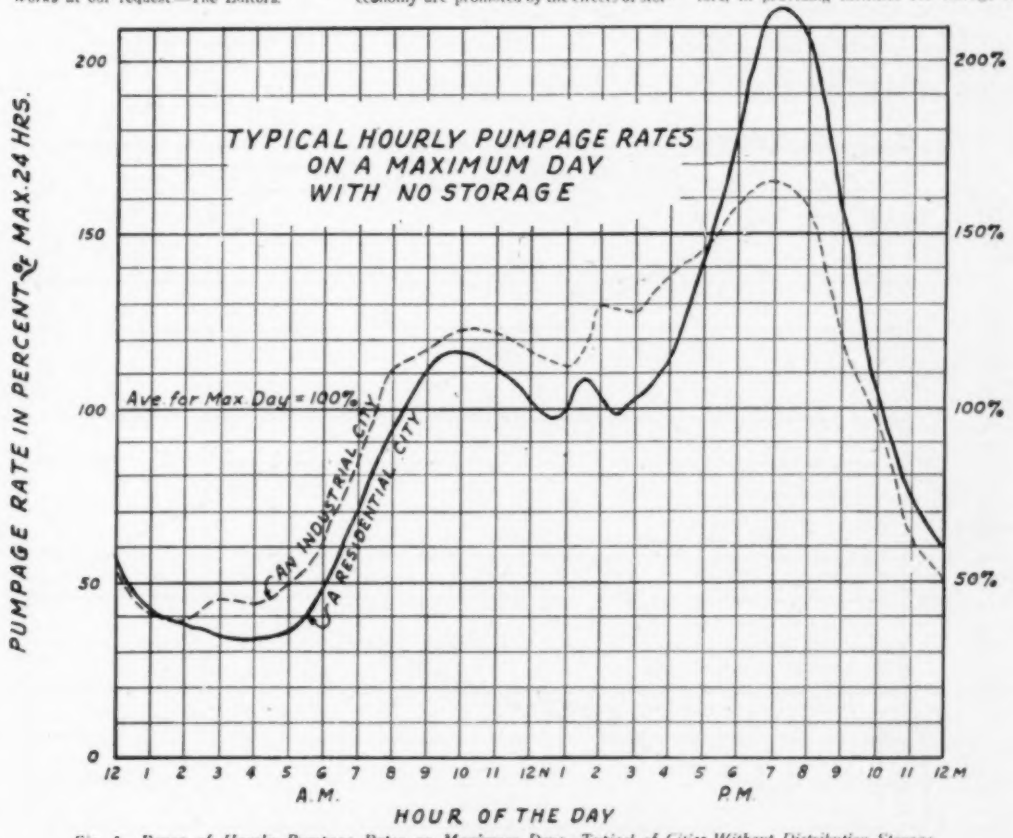


Fig. 1.—Range of Hourly Pumpage Rates on Maximum Days—Typical of Cities Without Distribution Storage. (Pattern for residential city compared with industrial city.)

is wise to allow a liberal percentage above average requirements in providing storage facilities.

The accompanying Table I is an analysis of the service requirements on five water works systems in cities varying from 37,000 to 320,000 population during years that are known to represent a well defined maximum in each city.

In these statistics the hourly pumpage rates were studied and correction was made for a small amount of elevated storage in several cases so that the figures would represent pumpage necessary to supply demand without storage. Fig. 1 shows diagrammatically the hourly rates of pumpage upon a maximum day for two cities, which represent common maximum and minimum conditions as to pumpage variation. There are some very large cities where use is more uniform. For more ready comparison, the pumpage rates have been expressed in percentage of the average pumpage rate (total pumpage) during the 24 hours of a maximum day. With information similar to this for any city, it is possible to compute the amount of storage which if most effectively liberated would make it possible to operate the pumps at a uniform rate throughout the 24 hours of a maximum day. In other instances, notably the small municipality, adequate storage can sometimes make possible the complete pumping requirement during the period of money-saving off-peak power rates.

Hourly variations in pumpage depend upon the character of the city in regard to similarity of use. Perhaps the most important consideration is the extent of industrial use. This can be and usually is a more or less uniform use. Upon the other hand, residential consumers use little or no water at night and make heavy demands at certain hours of the day, particularly during the early evening hours; and to this is added a very exceptional demand for lawn sprinkling on hot summer days. Recently, water used in cooling systems has placed an added burden on hot weather peak hours. In most cities the varying residential demand is more or less ironed out by commercial and industrial uses, and the extent of commercial and industrial use is probably largely accountable for differences in pumpage rates when comparing cities.

TABLE 1
Variations in Pumpage in Five Cities

Character of City	1 Residential	2 Industrial	3 Residential	4 Residential	5 Industrial
Population	37,366	100,426	110,468	307,000	320,000
Ave. pumpage MGD.	3.69	9.61	6.94	17.50	43.80
Gals. per capita	99	96	63	57	137
Max. 24 hrs. MGD.	5.09	17.42	13.66	30.65	70.20
Gals. per capita	136	174	124	100	220
Per cent of ave. day	138%	182%	196%	175%	160%
Max. hr. MGD.	8.05	35.80	20.36	53.00	115.70
Gals. per capita	216	358	278	174	360
Per cent of max. 24 hrs.	158%	205%	222%	172%	165%
Storage to Equalize Hour Peaks					
In gals. per capita	24	33	31	14	50
In % of max. 24 hrs.	18%	19%	25%	14%	23%
Reduced Pumpage Peak by Storage in—					
Gals. per capita	80	184	154	73	140
Per cent of max. 24 hrs.	37%	51%	55%	42%	39%

How Storage Improves Pressure

Fig. 2 is a cross section showing ground occupied by a city, and certain lines illustrating available water pressure created by a pumping station.

The line AB illustrates the drop in pressure in a case where no elevated storage exists, and pump pressure is so used up in deficient pipes that no pressure remains at the peak hour of the heaviest pumpage (demand) day at the remote end of the town.

With an elevated tank installed the pressure conditions are changed as follows upon a similar heavy pumpage day. Assume the storage is such that the pumps instead of running at a variable rate run a constant rate day and night. During the peak hour of use pressure will be represented by the line AC representing water flowing from the pumps. The line DC represents water flowing from the tank toward the pumping station, and line DE.

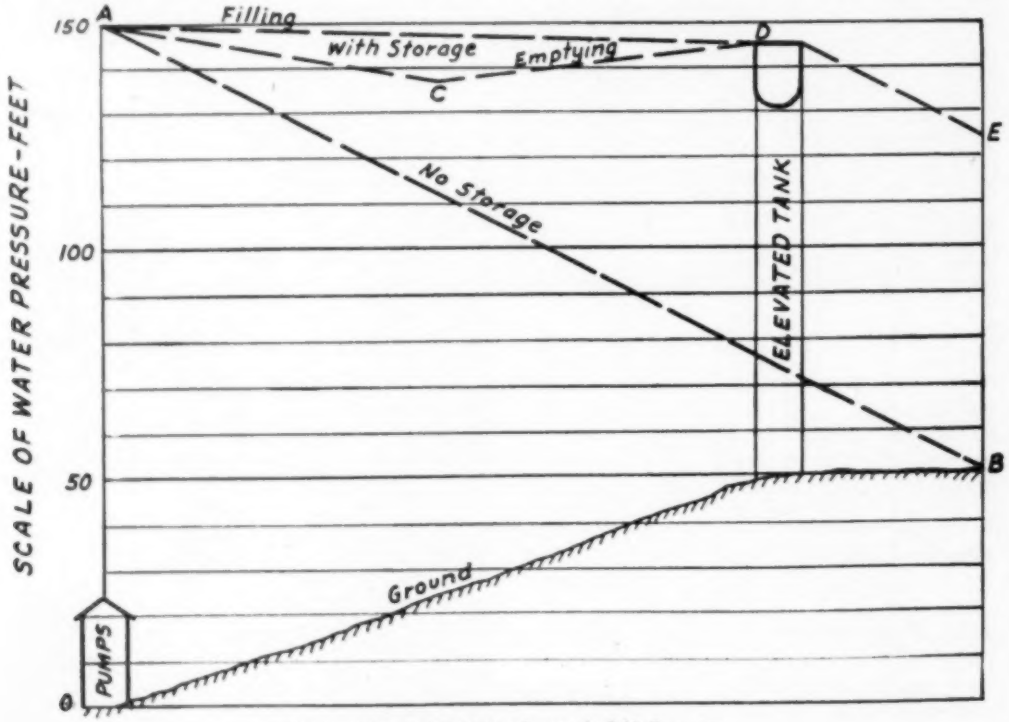


Fig. 2.—Effects of Distribution Storage Available Pressures (Shown for a maximum demand day.)

flowing from the tank away from the pumping station. The pressure losses at points between tank and pumping station are smaller than before because this district is being fed from two ends. This results in shorter travel, smaller velocities and greatly reduced friction losses. At points beyond the tank friction losses are the same as before but pressure is increased because the water is coming from the tank at a high elevation.

The conditions noted prevail approximately during the peak hours when use exceeds pumpage. After the peak is past and pumpage exceeds use, during night hours, the pressure approaches the line AD which represents conditions just as the tank is filled. The lines AC, DC and DE will be lower as the tank is depleted; and when an empty tank begins to fill the line AD will be much steeper.

The above illustrates the general result when storage is added without increasing the distribution feeders. Storage is an alternative to new and larger pipes and pumps.

Location and Height

A number of local conditions enter into the question of the best location for storage and the most suitable elevation. Storage is almost always an addition to an existing plant and therefore it must fit existing facilities as well as possible. The following general principles should be guides:

1—Storage should be reasonably close to heavy peak drafts of water and on the opposite side of such points from the pumping station.

2—Elevated storage at the pumps helps the pumps but does not add to the capacity of the distribution system, which involves more than half the cost of the average water works.

3—Elevated storage on the opposite side of heavy draft permits water to be fed from both ends of the distribution system, thus nearly or quite doubling the capacity of the feeders.

4—The top of the stored water will necessarily be slightly below the maximum existing pressure plane of the pumps; but must *not* be too high to fill in the night hours of a peak day. The depth should be as shallow as reasonably possible; 20 to 25 feet is common.

5—The value of storage is largely lost when too far away. Costly pipes can overbalance the advantage of storage.

Amount of Storage Required

Fig. 3 shows the amount of storage necessary upon a maximum day to reduce the pumpage to a constant rate throughout the 24 hours of such a day. It also shows the effect of various lesser amounts of storage in reducing the peak hour requirement. The curve shown on the diagram is a median line between the extremes represented by dots upon the diagram. Each dot represents a computation for one of the five cities shown in Table I. It will be observed that a large benefit in pumpage reduction can be secured from a relatively small installation in storage.

These data indicate upon the average that 20 per cent of the maximum day in elevated storage may be expected to reduce the maximum hourly peak about 45 per cent. Or, expressed in another way, in the five cities studied 30 gallons per capita in storage might be expected to reduce the maximum hourly pumpage peak rate 126 gallons per capita if the storage is most effectively used.

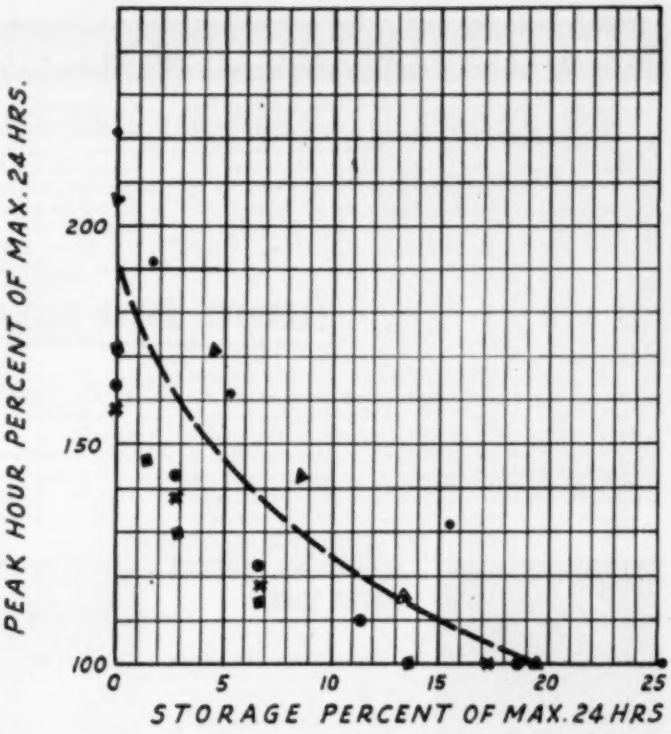


Fig. 3.—Effects of Storage on Pumpage Peaks in Five Cities
(Expressed in per cent of max. 24 hr. pumpage on maximum demand days. Each symbol of different design represents one of the five cities covered in Table I.)

In determining how much elevated storage shall be built, consideration is properly given to the existing installations in water supply facilities. The system as a whole must be designed for the maximum requirements for water, which must include the maximum requirements for fire protection if good fire protection service is furnished. In each case a proper installation is a coordination between elevated storage, water supply, pumps and distribution pipe facilities, so adjusting these facilities means that adequate service is furnished at least cost.

Fire Protection

One of the most important benefits from elevated storage is the ability to respond instantly to the heavy draft of water required for fire protection. In the smaller towns this furnishes an especially valuable service while pumps are being started, for many such systems pump intermittently.

In Table 2, column 4, there is shown the rates at which water should be furnished to comply with recommendations of the National Board of Fire Underwriters for cities of various sizes. For comparison there is also shown the average and maximum rates of pumpage based upon the average of the five cities shown in Table I.

For the smallest town the fire demand is nearly five times the peak hour use, and pumps and distribution system must be designed accordingly without storage, bearing in mind that about 50 per cent above the average domestic demand plus the fire demand must be accommodated.

In towns over 25,000 the peak hour and the fire demand are about equal. In cities of 100,000 or more the combined domestic and fire demand is less than the domestic peak hour demand, and fire protection ceases to be a controlling factor so far as rates of pumpage are concerned.

It should be borne in mind that adequate fire protection provides for very rare emergencies. Likewise, the maximum storage for domestic peak hours is needed on only a few days in exceptional years, and usually an installation contains a reserve for future growth. Therefore an installation proportioned for domestic service is an important addition to the fire protection. It alone provides ample water for the great majority of fires, and the first and more important water in exceptional fires. Its great value is its readiness to serve.

Types of Distribution Storage

Various types of distribution storage are best adapted to special conditions. These types are summarized as follows:

1—Most of the cities in this country are relatively flat and the elevated tank of steel is most widely used. It is now built in shallow depths so that all the water is stored at sufficient elevation to be useful. Sizes as large as 2 mg. are available. Recent designs present a very pleasing appearance.

(Continued on page 40)

CHICAGO BRIDGE & IRON COMPANY

Since 1893, Chicago Bridge & Iron Company has been designing, fabricating and erecting storage tanks and many other types of plate work for municipal water systems and sewage plants throughout the country. These 59 years of experience have led to many structural improvements, and faster, less costly erection methods that can mean long term savings for your city. This long experience of the Chicago Bridge & Iron Company has also resulted in the constant improvement of our tank designs to effect a more pleasing appearance.

Structures for municipal storage are built by the Chicago Bridge & Iron Company in accordance with specifications of the American Water Works Association. Four strategically located plants in Birmingham, Alabama . . . . Chicago, Illinois . . . . Salt Lake City, Utah . . . . and Greenville, Pennsylvania are always ready to supply your needs.

ELEVATED WATER TANKS

Horton elevated water tanks are especially designed to provide dependable, low cost water service for cities without nearby natural elevation. For by storing water above points of consumption, they utilize the many advantages of gravity pressure. Horton elevated tanks can increase water pressure, decrease pressure variations and lower pumping costs throughout a water system. They can reduce insurance rates and, most important, they can increase water customer satisfaction.

Horton elevated water tanks are built in four basic types—ellipsoidal bottom tanks, radial-cone bottom tanks, waterspheres, and Horton spheroidal tanks—to meet your specific requirements. When requesting estimates or quotations, please include capacity, heighth to bottom and location.

ELLIPSOIDAL BOTTOM WATER TANK

This graceful medium-capacity welded steel water tank has a relatively large diameter and shallow depth to help reduce water pressure variations. The design may be somewhat modified to meet specific requirements.

Gallons Capacity	Tank Dimensions	
	Diameter	Range
50,000	22'0"	19'0"
60,000	24'0"	19'0"
75,000	26'0"	21'0"
100,000	28'0"	24'0"
125,000	30'0"	25'5"
150,000	32'0"	27'6"
200,000	36'0"	29'6"
250,000	40'0"	29'0"
300,000	43'0"	30'0"
400,000	46'0"	35'0"
500,000	50'0"	37'6"

WATERSPHERE

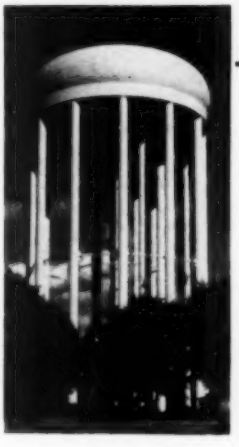
This modern tank is ideal for installation in residential or other high value areas. All piping connections and a fixed ladder for inspections are located inside the supporting column. Access to the inside of this column is provided by a door at ground level.

CAPACITY IN GALLONS	DIAMETER OF SPHERE
25,000	19'4"
30,000	20'4"
40,000	22'4"
50,000	24'0"
60,000	25'6"
75,000	27'4"
100,000	30'0"
150,000	34'0"
200,000	37'6"
250,000	40'6"

RADIAL-CONE BOTTOM WATER TANK

This functional design permits us to build a large capacity water tank with a relatively low range in head. The result is substantially lower pumping costs for a given amount of water.

Gallons Capacity	Tank Dimensions	
	Diameter	Range
500,000	60'4"	25'
750,000	74'3"	25'
750,000	67'6"	30'
1,000,000	86'0"	25'
1,000,000	78'0"	30'
1,000,000	71'6"	35'
1,500,000	104'0"	25'
1,500,000	96'0"	30'
1,500,000	88'0"	35'
2,000,000	112'0"	30'
2,000,000	104'0"	35'
2,500,000	114'0"	35'
3,000,000	117'0"	40'



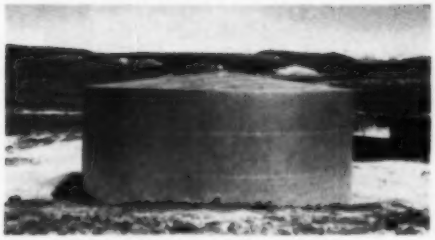
HORTONSPHEROIDAL WATER TANK

These large capacity welded steel water storage tanks combine the advantages of excellent overall appearance with a very low range in head. Functional design allows an even distribution of weight to all supports. Some exterior modifications—such as special designs for the central riser—may be made to achieve a desired architectural effect.

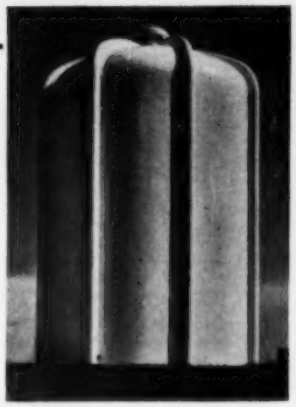
Gallons Capacity	Tank Dimensions	
	Diameter	Range
1,000,000	87'6"	25'
1,000,000	81'0"	30'
1,500,000	92'0"	35'
2,000,000	106'0"	35'
2,500,000	117'0"	35'
3,000,000	120'0"	40'

CHICAGO BRIDGE & IRON COMPANY

WELDED STEEL RESERVOIRS



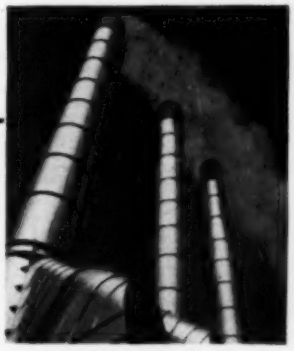
The Chicago Bridge & Iron Company builds welded steel reservoirs and standpipes in standard capacities ranging up to 10,000,000 gallons. Special designs and modifications similar to those on the installation shown at the right can be adapted to every capacity. Our careful fabrication and erection methods assure a longer service life. Smooth tank surfaces make painting easier and maintenance less costly.



HORTONSPHERE FOR DIGESTER GAS

These efficient welded steel containers store digester gas under pressure for heating purposes, or to generate power and light. When the gas demand exceeds the supply, a Hortonsphere can make up the difference—or when the supply exceeds the demand, surplus gas can be stored in a Hortonsphere. A Hortonsphere also makes it possible to increase the capacity of a gas distribution system without increasing production facilities. Hortonspheres have only one set of pipe connections and fittings. Capacities range up to 1,000,000 cu. ft.

STEEL PLATE WORK



Steel plate work like the towering self supporting smokestacks, shown at the right, offers no construction problem to our design, fabrication and erection departments. Their years of specialized experience in supplying water and sewage plants throughout the country with all types of plate work enables them to tackle every job with complete confidence.

When requesting quotations on steel work, please send us complete plans and specifications.

PHOSCOTE PROCESS

The Phoscote Process of pickling and painting steel plates, angles, channels, etc. will save maintenance dollars and prolong the life of tanks and special structures. The process, as performed at our plants, removes mill scale with sulphuric acid, plus a wash, and a phosphoric acid treatment. This provides a dry, clean surface coated with a thin layer of iron phosphate which improves the bond between the prime coat of paint and the steel.

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TABLE 2
Rates of Pumpage Required in Cities of Various Sizes

Population	1 Ave. MGD. at 100 Gals. per Capita 100%	2 Probable Peak 24 Hrs. MGD. 167%	3 Probable Peak Hr. MGD. 308%	4 Max. Rate for Fire Protection MGD.	5 Storage for Hourly Peaks 20% of Max. Day
1,000	.1	.17	.31	1.44	.033
2,000	.2	.33	.61	2.15	.066
4,000	.4	.67	1.24	2.86	.124
10,000	1.0	1.67	3.08	4.30	.334
25,000	2.5	4.66	8.64	7.15	.932
60,000	6.0	10.00	18.50	10.00	2.00
100,000	10.0	16.70	30.80	12.90	3.34
200,000	20.0	33.40	61.60	17.20	6.68

2—There are some situations where elevated ground is available but not high enough for a concrete reservoir on the ground. In such situations circular steel tanks up to 40 to 60 ft. high and of large capacity can be built for less than half the cost of elevated tanks per unit of capacity. Such tanks can sometimes be scattered at more than one location with beneficial results. For the higher of such tanks all the water may not be fully useful but it furnishes a cheap support for the more useful elevated water.

3—Many cities are so fortunate as to have elevated ground sufficiently high to accommodate elevated reservoirs. These cost about half as much as most elevated tanks. Most recent reservoirs are covered, built of reinforced concrete buried in the ground, and have long life with small maintenance costs. Reasonable cost favors large capacities. In some installations the entire fire protection water is stored in addition to domestic requirements. As much as 100 to 300 gallons per capita is stored in some cities.

4—Where elevated ground is not available it is sometimes economical to build concrete reservoirs or steel tanks on the ground, fill them at night with water bled from the mains and repump stored water back into the mains by remote controlled or automatically controlled electric pumps. The capitalized cost of repumping should, of course, be charged to the installation. In cost comparisons such pumping may be less costly than might be thought if operation is required only a few hours per day during a limited portion of the year.

Operation of Storage

Money should be conserved for use. Likewise water stored should be conserved so that it will be available when needed. There is little use for storage during about 80 per cent of the normal year. With storage it becomes possible to run pumps at a nearly uniform rate, with attendant advantages of economy, and on normal days to utilize only a few feet of the upper part of the storage. The storage should only be materially exhausted during the peak hours of the heavy pumpage days, and always refilled before morning.

Water works men are now more firm than ever in the belief that storage on the distribution system pays its way in the reliability and economy of water service.

FIRE HYDRANT FLOW GAGE

By A. A. HIRSCH*
State Dept. of Education, Baton Rouge, La.

Of the several methods in vogue for hydrant flow measurement, namely the special pitot tube-gage combination, the stream trajectory, the short tube with terminal orifice, and the velocity head reading by means of a pressure gage on a closed cap, the last named is the one most generally employed by reason of its simplicity in principal and equipment.

The Procedure

In determining flow from a fire hydrant by the pressure gage method all that is needed is to connect an accurate gage to the closed nozzle, and discharge the hydrant through the other nozzle. The flowing nozzle may be considered as a "short-tube"

Figure 1.—Dial of pressure gage calibrated to read directly fire hydrant flow from a 2½-inch nozzle.

and its flow calculated from the usual orifice formula, but using an orifice coefficient of 0.9 instead of the familiar 0.61 which holds for a sharp edged orifice. Thus

Flow (cu. ft./sec.) = C A V where C = fire hydrant orifice coefficient = 0.9.

$$A = \text{area of nozzle (sq. ft.)} = 0.785 \times \frac{\text{Diameter}^2_{\text{(inches)}}}{144} = 0.00545\ \text{Diameter}^2_{\text{(inches)}}$$

$$V = \sqrt{2\,g\,h_{\text{ft. water}}} = \sqrt{2 \times 32.16 \times 2.31 \times \text{Pressure}_{\text{psi.}}}$$ the pressure reading being taken off the closed nozzle

$$= 12.2\sqrt{\text{Pressure}_{\text{psi.}}}$$

Substituting in the first equation:

$$\text{Flow (gpm.)} = 7.48 \times 60 \times 0.9 \times 0.00545\ \text{Diameter}^2 \times 12.2\sqrt{\text{Pressure}_{\text{psi.}}}$$

$$= 27\ \text{Diameter}^2_{\text{(inches)}}\sqrt{\text{Pressure}_{\text{psi.}}}$$

This is the familiar form commonly used to calculate the discharge from a fire hydrant.

Ordinarily the 2½-inch nozzle is used, as the 4- or 4½-inch nozzles do not conform with accuracy to a simple formula. Substituting the value of 2½ inches for the diameter in the above formula there results

$$\text{Flow (gpm. through 2½ in. nozzle)} = 27 \times 2.5^2 \times \sqrt{\text{Pressure}_{\text{psi.}}} = 168.7\sqrt{\text{Pressure}_{\text{psi.}}}$$

from which the discharge through a 2½-inch hydrant nozzle may be conveniently calculated.

The Self-Calculating Gage

Inasmuch as a given velocity head on the pressure gage corresponds to a fixed discharge the gage may be calibrated to read this flow directly and thereby obviate the need for calculation. A dial so calibrated is illustrated in Fig. 1. By marking off a dial in this manner the gage may be used in hydrant flow studies to facilitate discharge adjustments and to enable flow evaluation on the spot without calculations or conversions. Fig. 1 may also be used as an approximate solution to the hydrant formula for a 2½-inch nozzle rather than perform the numerical substitutions.

The accuracy of the pressure gage should be checked on a cold test apparatus, especially in the low pressure range below 500 gpm. where slight inaccuracy causes relatively large errors in the indicated discharge. If the test gage is off the needle position may be reset, the linkage between hollow spring and sector adjusted as required, or a calibration curve drawn to show the true pressure corresponding to any gage reading. From Fig. 1 it will be noted that below a flow of about 250 gpm. the type of pressure gage as illustrated is inapplicable since it fails to deflect.

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The finest equipment available for measuring and controlling fluid flows

1. Venturi Tubes – Most desirable form of primary device for use with inferential meters. Furnished for high or low pressures in cast-iron, cast steel, steel plate, bronze or combinations. Used for measurement of hot and cold water, gases, air, sewage, sludge or chemical bearing liquids.

2. "S" Parabolic Flume – Widely used for measuring sewage and industrial wastes flowing in partially filled pipe lines, in pipe sizes from 3" to 36" inclusive. May be used alone as an indicating device or with water float operated meter for recording and totalizing of flow.

3. Filter Gauges – Essential for correct filter plant operation. These gauges are available for indicating and recording rate of flow and loss of head. Bed expansion function may be included. Gauges are furnished for operating table or floor stand mounting.

4. Type MO Meter – Most accurate industrial inferential type instrument available. Measures within ±2% over ranges up to 20 to 1, using Venturi tube, flow nozzle or orifice plate as primary device. Evenly spaced rectangular chart is easy to read. Wall bracket, panel mounting or floor stand. Designed for water, sewage, sludge, industrial liquors.

5. Air Inlet (Vacuum Breaking) Valves Furnished in 4", 6", 8" and 10" inlet sizes, these valves eliminate possibility of collapse in thin walled pipes due to sudden drop in pressure in gravity flow lines. Float is buoyed to its seat by water pressure and upon loss of buoyancy, float falls admitting air and breaking vacuum.

6. Air Release Valves – Type AGFD air release valves vent air accumulations in pipe lines, increasing pumping efficiency and eliminating air binding at high points in line. Simple, rugged in construction, these valves are obtainable in 1" and 2" inlet sizes in working pressure to 250 p.s.i. Special valves available for pressures to 800 p.s.i.

7. Type H Meter – Operates in conjunction with Venturi tubes, flow nozzles, or orifice plates on differential heads of 64 inches and 114 inches of water. Measures over respective ranges of 10 to 1 and 13 to 1 within ±2%. Wall bracket, panel mounting or floor stand, as desired. For measurement of water, air, sewage, sludge and industrial liquors. Instrument utilizes evenly spaced circular charts.

8. Flow Controllers Type "S" controllers of the Guillotine-balanced valve design are necessary units for correct filter operation. Controllers maintain constant flow regardless of variation of loss of head through filter. Sizes from 3" to 24" inclusive, they maintain control within ±3% over 5 to 1 range.

PITOT EQUIPMENT

Portable pitot rods, manometers and recorders, when used together furnish an over-all picture of actual operating efficiency of distribution systems. By their use, leaks and line breaks in grid systems are readily located.

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AUTOMATIC "Cushioned" VALVES

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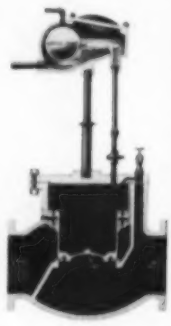

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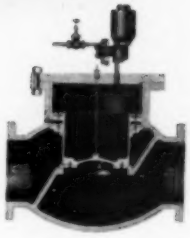
COLD WATER FLOAT VALVE

- High Pressure—for automatically maintaining a uniform water level in tanks, standpipes, reservoirs, railroad track pans, etc.
- Low Pressure—for automatically maintaining a sensitive water level control in mixing chambers, coagulating basins, etc.
- Air and water cushioning assure smooth operation and long life.
- For 150# WP and 250# WP. Sizes ½" to 36".
- Available in globe or angle body design.



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SOLENOID-OPERATED ELECTRIC WATER SERVICE VALVE

- For any remote control application.
- Normally open or normally closed operating sequence.
- Air and water cushioning prevents shock or hammer and permits smooth operation at all times.
- Available in globe or angle body design.
- Sizes 2" to 36" for pressures 150 to 250 psi.

"Cushioned"

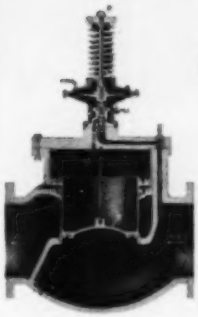
WATER PRESSURE REDUCING VALVE

- For automatically maintaining a uniform outlet pressure, despite variable inlet pressure.
- Opening and closing is cushioned to prevent water hammer and shock.
- Available in globe or angle body design.
- Furnished in sizes 3" to 36" for pressures 150 to 250 psi.

New technical bulletins describing the features and operating advantages of these specialty valves—gladly sent on request.

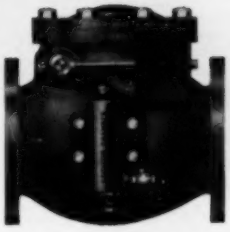
A CORROSIVE PART DURING OPERATION

AND CONSTRUCTED ESPECIALLY FOR MUNICIPAL WATER WORKS SYSTEMS



"Cushioned" ALTITUDE CONTROL VALVE

- Maintains water level control within ranges of 3" to 12" for elevated tanks, standpipes or reservoirs.
- Available with electrical attachment to permit emergency closing from remote push-button control station.
- Inherent air and water cushioning prevents any water surges or shock in operation.
- Furnished in sizes 2" to 36" for pressures 150 psi. to 250 psi.



"Cushioned" SWING CHECK VALVE

- Usually installed on pump discharge line and automatically prevents back flow into pump.
- Rapid closure when pump is shut down.
- Can be installed either horizontally or vertically.
- Especially designed with cushion chamber on side of body to prevent any slapping or banging against seat on closing.
- Available in sizes 3" to 36" for pressures 150 psi. to 250 psi.

"Cushioned" SURGE RELIEF VALVE

- To protect water lines against excessive surges in the system.
- Automatically opens when inlet pressure exceeds adjustment of the pilot.
- Patented double cushioning design prevents all slam or hammer.
- Available in globe or angle body pattern.
- Regularly furnished in sizes 2½" to 16" for pressures 125 psi. to 400 psi.

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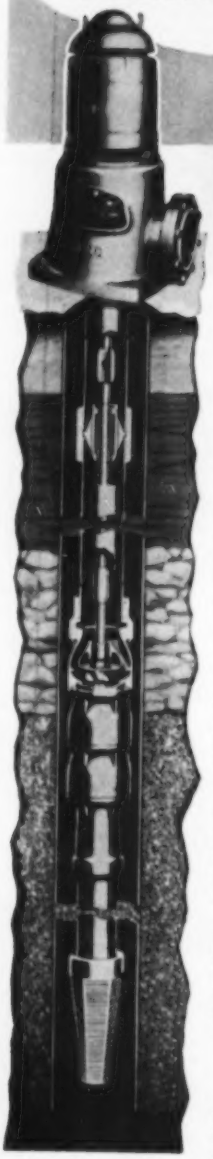
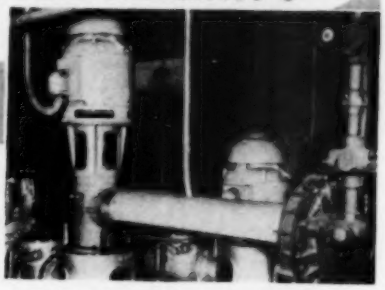
Condensed reference data

DEMING VERTICAL TURBINE PUMPS



Bowl, Column and Shaft Assembly

Typical Municipal installation of a Deming Turbine Pump with Unit Drive Head (vertical hollow-shaft electric motor).



A dual installation with one pump equipped with Combination Drive direct-connected to steam turbine for emergency use.

ADVANTAGES

Successful performance of Deming Vertical Turbine Pumps in municipal service is due to their following advantages:

WATER LUBRICATION. Requires minimum attention and eliminates any possibility of contaminating water supply with oil lubricants. (Oil lubricated pumps are also available for special conditions.)

LOW OPERATING COSTS. Efficient hydraulic design produces more water with less power. Also, pumps can be run at night when current rates are lower.

SUSTAINED HIGH EFFICIENCY. Semi-enclosed impellers are easily adjustable from the surface to compensate for changes in well conditions or for wear after long periods of service.

LOW MAINTENANCE COSTS. Vital parts of pumps are made from corrosion-resisting metals. Ample size of shaft and related components are engineered for heavy duty service.

PRINCIPAL COMPONENTS

Deming Vertical Turbine Pumps are comprised of three principal component assemblies:

(1) The DRIVE or HEAD assembly.
(2) The COLUMN and SHAFT assembly.
(3) The BOWL ASSEMBLY or PUMPING ELEMENT.

Those three principal components are manufactured in a wide range of standard sizes which may be quickly assembled into almost limitless combinations to meet specific conditions and requirements.

CAPACITIES and APPLICATIONS

Deming Vertical Turbine Pumps are designed for wells 4 to 16 inches or larger in a full range of capacities from 15 to more than 3500 gallons per minute.

In addition to their applications for deep or shallow well service, these pumps are in wide use for pumping from reservoirs, rivers, and other sources.

TYPES OF DRIVE

UNIT DRIVE HEAD for installations where electric power is available. Vertical hollowshaft motors with weatherproof housing are carried in stock for prompt shipment. Totally enclosed and explosion-proof motors are available for special conditions.

COMBINATION MOTOR-RIGHT ANGLE DRIVE for installations where an auxiliary source of power must be available. Engine or other power-unit is direct-connected through flexible shaft to right angle drive. Motor may be removed and operated through drive only.

Send for Bulletin 4700

Construction details and other information about Deming Vertical Turbine Pumps are available in BULLETIN 4700. Write for a copy.

THE DEMING COMPANY • 557 BROADWAY • SALEM, OHIO

PURCHASE AND MAINTENANCE OF DEEP-WELL PUMPS*

By L. J. ALEXANDER

Design Engr., Southern California Water Co., Los Angeles, Calif.

THE Southern California Water Co. has 107 turbine pumps in operation and purchases an average of 10 complete units each year. These pumps are located in 29 operating districts. Geographically, the districts are scatttered from the vicinity of Sacramento to the Imperial Valley. They operate under climatic conditions ranging from the hot, dry desert to the snow-clad San Bernardino mountains. The wells in which the pumps operate are located at elevations varying from sea level to more than 7,000 ft.; the motors driving them vary in size from 7½ to 150 hp., and the capacity range is from about 100 to more than 2,200 gpm. In direct lift of water from the well, the variation is from just a few feet to more than 500 ft. below the surface.

The wide range of pumping conditions provides opportunities to shift pumps from one location to another, thereby practically eliminating the factor of obsolescence. A pump can always be installed in a well or system where it will operate to best advantage. With specifications standardized, it is possible to make these transfers even though there is considerable variation in character and quality of the water being pumped.

Wells and Water Quality

Wells drilled in Southern California are of two types: the California cable tool and the rotary gravel envelope. The cable tool method was developed in the early days of well drilling in Southern California because of the character of the geological formations into which wells must be drilled. These are all unconsolidated formations of the Recent, Pleistocene and Pliocene geologic epochs. The unconsolidation is such that open-hole drilling is impossible; the well casing must follow the drill. After the well is drilled, the casing, which is then in place, is perforated opposite water-bearing formations.

Rotary gravel envelope wells have preperforated casings set in the drilled and well-mudded hole. Gravel is then placed between the casing and the wall of the drilled hole.

The Southern California Water Co. has wells of both types, with depths ranging from less than 200 ft. to more than 1,900 ft. The unconsolidated formations in which these wells are drilled are so unstable that, regardless of the type of well, it is often impossible to keep out fine sand or silt. Even after very careful development of the well, it is occasionally necessary to resort to the use of a column check valve in the construction of a pump. In doing this a column check valve is installed immediately above the pump bowls to prevent water from draining out of the pump, with a consequent reversal of the flow from the well into the formation.

Sand within the water passages of the pump literally blasts away metal of bowls, impellers, shaft, casing and tubing. Experience has shown that bronze withstands this sand cutting better than any other metal. Porcelain-enameled cast-iron impellers have been tried, as porcelain is harder than sand and, thus, might be expected to withstand the abraison; but sand cuts into the cast iron where the enamel has been machined off, and cavities develop between the porcelain and iron. It is only a matter of time until the porcelain spalls, due to corrosion of the iron.

Because many of these formations from which water is extracted were laid down under water, there are large areas where gases such as methane, carbon dioxide or hydrogen sulfide are entrained. These gases (or air from water falling from perforations above pumping water level) cause turbulence in the pump, and, in turn, excessive corrosion. Bronze and stainless steel withstand such corrosion better than iron or steel. In the pump column, at the top of the bowls, a short section of bronze tube will often withstand the corrosion caused by turbulence.

stainless steel shaft, bronze bowls and impellers in the bowl assembly, a 5-ft. section of bronze oil tube, a stainless steel line shaft from bowls to static water level, with a coating of coal-tar enamel outside the oil tube and inside and outside the eduction pipe.

To check corrosive waters, the Wintroath Pump Co. has demonstrated that the better the grade of metal, the more resistant it is to corrosion. Many pump manufacturers, for their standard sales product, use an ordinary run of foundry gray iron. The Wintroath analysis shows a rather high electric potential between ordinary gray iron, bronze and stainless steel, which seems to be additional proof of what practice has long demonstrated: that the

TABLE I
Analysis of Water

	City Creek	Foothill	Garvey	Wadsworth	Golden West	Avalon	Colden	Pacific
Sodium	104.4	37.7	19.6	378.6	32.2	49.5	57.3	68.7
Calcium	1.2	32.1	27.6	10.0	57.5	69.6	106.8	105.2
Magnesium	Trace	6.7	11.2	2.5	10.3	13.4	21.8	42.7
Sulfate (SO_4)	84.5	7.2	18.2	3.8	44.1	91.2	197.3	179.0
Chlorine	19.0	12.0	20.0	198.0	29.1	33.0	53.5	82.0
HCO_3	109.3	291.3	164.7	699.0	297.3	231.7	244.0	336.5
Total solids	319.0	321.8	294.5	1319.9	392.9	492.4	698.4	839.1
Carbonate hardness	3.0	107.5	135.0	35.0	170.0	195.0	200.0	275.0
Other hardness	....	....	5.0	....	16.5	34.0	156.5	162.0
Total hardness	3.0	107.5	140.0	35.0	186.5	229.0	356.5	437.0

The well waters pumped represent a wide range in chemical characteristics. Hardness varies from just a few to more than 500 ppm.; the pH is between about 7.3 and 8.0. Total solids vary from less than 100 ppm. to a maximum of 1,500 ppm. In several wells, free carbon dioxide appears and, in a large number, free hydrogen sulfide. Some waters have no trace of either iron or manganese; others have as high as 2 ppm. iron and 1 ppm. manganese. Table 1 shows this wide range of chemical character in the water produced. It has not been possible to relate corrosion rates directly to the acid radicals contained in natural waters.

The most troublesome conditions under which pumps operate exist in those wells in which the waters have been highly contaminated with the iron and sulfur group of slime-forming organisms, and contain as much as 2 ppm. iron and 1 ppm. manganese and have a high concentration of free hydrogen sulfide. Such waters are devoid of dissolved oxygen, but the slime-forming organisms are anaerobic. Slime coatings of considerable thickness will form even on highly polished rotating parts, such as the impellers. As the slime increases in thickness, the water passage space is reduced in area; and the efficiency of the unit reduced.. Occasionally graphitic corrosion takes place to an alarming degree where these slime-forming organisms are present. Bronze parts are the least affected by the slime formers.

Corrosion

Corrosion of turbine pumps results from several causes: chemically corrosive waters, entrained gases, bacteria and differences in electric potential between parts of the unit. How each factor operates or affects the other is not known, but it is obvious that corrosion does occur and that preventive measures are necessary.

In extreme corrosion, whatever the cause, the best preventive measures are to use a

finer the metallurgy, the better the completed product.

Speed of rotation is another factor. It seems that the higher the speed, the greater the rate of corrosion. The author has found no satisfactory explanation of this correlation, and cannot determine whether it is due to corrosion alone, or partly to the turbulence caused by high velocity.

No attempt has been made to weigh individual parts of the pump to determine the extent of corrosion or wear in terms of the percentage of metal lost. Such an analysis in turbine pumps has little practical value because corrosion and wear never take place uniformly. A section of pump casing may lose less than 1 per cent by weight and still be unsafe because the casing is pitted. If pitting is allowed to continue, holes will cut through the casing and, under the high head of water in the pump column, act as nozzles. Wells have been damaged by such holes drilled through the well casing, and the loss of water through holes causes appreciable loss in pump efficiency. Corrosion and pitting at or near threads of the casing so weakens the pipe that failure can occur at a joint. When this occurs, the entire weight load of the pump and the hydrostatic thrust of water load are transmitted to the motor bearing and the rotating impellers. Such loads will wreck the entire unit.

In the pump bowls, a fraction of one per cent loss in weight, if in certain places, may be serious. On the other hand, if corrosion or sand cutting is uniform throughout, a 15 or 20 per cent loss in weight may not be serious.

Corrosion of the tubing may permit water under high head to enter the peripheral space between the tubing and the rotating pump shaft. Water will then shortly find its way out through the top of the tubing. When this occurs, the motor windings are often sprayed with water, resulting in a burned-out motor. Of less serious conse-

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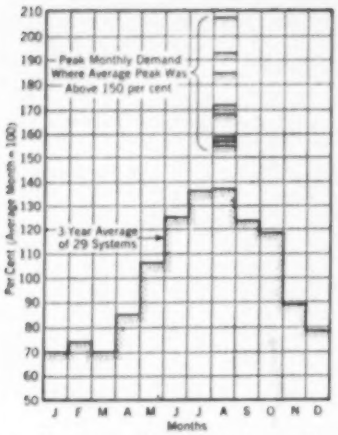
Peak Monthly Demand Where Average Peak Was Above 150 per cent
3 Year Average of 29 Systems
Per Cent (Average Month = 100)
J F M A M J J A S O N D
Months

Fig. 1. Average Monthly Production for All Systems

quence, but equally troublesome, is the resulting corrosion of the line shafting. The company's specifications do not permit a packing gland at the top of the tubing, because a packing gland prevents the appearance of oil and water at the pump head. When even a very small hole appears in the tubing it can be detected quickly and immediately repaired.

Very slight wear in the motor bearings, even a fraction of one per cent, may change the position of the impellers in the bowls, and cause them to wear excessively. The efficiency of the unit is lowered almost immediately, even before serious wear occurs. Excessive wear in motor bearings also causes misalignment of bearing housings. Oil is thrown out of the housing and, in a very short time, saturates the motor windings so thoroughly that nothing short of rewinding the motor will save it.

No mathematical relationship or formula can be developed or deduced to replace experience and visual inspection in the choice and extent of repairs and replacements to parts of the pump, when it is pulled for overhaul.

Variation in Demand

The variation of consumer demand in arid countries is great. All living things require water regularly, but in Southern California nature provides water only in the winter rainy season. Irrigation is therefore necessary. Domestic water service must provide for irrigation of lawns, shrubs and flower gardens, as well as for industrial and household consumption.

Fig. 1 shows the Southern California Water Co. monthly production compared to the average month (taken as 100 per cent). Together with the 3-year average for the 29 systems, the maximum months for several of the smaller systems are also shown. It appears that the smaller the system, the greater the peak demand. The average day of the maximum month averages nearly 140 per cent of the yearly average day; but the average day varies widely in the various systems. The average daily demand for 1945 is shown in Table II. This table also shows the relationship of the maximum day to the average day.

There is an even greater variation in hourly demand. Fig. 2 shows the average variation for each hour of the maximum day. The broken line represents the average of three consecutive maximum days in the Lennox system in 1942.

These curves all show the necessity for a large available capacity in primary pumping equipment. On the other hand, they show that, for large portions of the year, much of the equipment must remain idle. Experience has demonstrated that idle equipment deteriorates nearly as rapidly as operating equipment. The causes may be different, but replacements are just as costly. To overcome this problem partially, all equipment is operated at least once a week.

Weekly operation keeps the well in good order, dries out the motor windings, prevents "freezing" of bearings—particularly in the line shaft—tends to reduce the accumulation of slime growths and assures the operators that the equipment is in good order. This last is important because all equipment must "cut in" quickly and automatically in case of fire.

Planned Operation

Although all equipment is automatic, the time each unit operates can be predetermined. The general plan of operation to assure an adequate dependable primary supply is laid out in the engineering department. This plan is based on a study of the distribution pipe system and the location of the various pumping plants. Elevated storage is always considered as a balance against the maximum hour, and it is also desirable to consider it as a safety factor. Each plant is automatic, operation being controlled by pressures within the adjacent distribution system. Other factors entering into the setting of these controlling pressure ranges are: the quality of water produced at the plant, the efficiency of equipment, variations in demand, the needs of fire protection and the manpower available to operate the equipment.

The carrying out of these planned operations is under the direction of the construction engineer, who has charge of all field work on new construction, as well as maintenance, repair, replacement and operation. The district superintendents, of course, are "on the ground" and carry out most of the details of the operation of pumping plants.

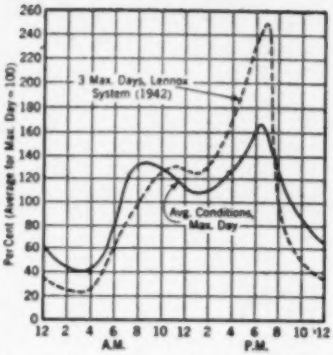

Fig. 2. Average Demand on a Maximum Day

Checks on Operation

To check the overall engineering plan, periodic pressure surveys are made. Complaints of poor water service are also checked against planned operation. The operation policy is to render an adequate and dependable water supply to all consumers at all times. During the war years, this has at times been difficult, but, with a little more time and the delivery of some needed materials, the policy will again be maintained.

All the factors involved in such operation make necessary continuous checks on equipment. In doing this, three principal checks are made regularly on all operating equipment.

The first check is made in the statistical branch of the engineering department. All field pumping records are assembled and checked in the office and the performance of each pumping plant is checked each month. A computation is made of the power in kilowatt hours consumed in pumping 100 cu. ft. of water (the company's unit of water measurement). This figure is balanced against the pumping water level in

TABLE II
System Demands

System	County	No. of Customers* 3/13/46	Gals. per Customer* 1945	Max. Day, Per Cent of Avg. Day, 1945
Artesia	Los Angeles	547	423	199
Barstow†	San Bernardino	876	822	191
Bear Valley	San Bernardino	655	202	386
Bloomington	San Bernardino	376	294	193
Calipatria‡	Imperial	290	1621	...
Niland	Imperial	125	...	...
Bell	Los Angeles	2,549	460	174
Florence-Graham	Los Angeles	5,986	695	135
Cardena	Los Angeles	4,048	432	230
Lawndale	Los Angeles	2,747	378	201
Lennox	Los Angeles	4,569	370	172
Normandie	Los Angeles	1,650	324	198
So. Los Angeles	Los Angeles	7,905	359	208
Claremont	Los Angeles	1,185	707	311
Cypress	Orange	126	386	242
Highland	San Bernardino	603	388	188
Hollyda e	Los Angeles	1,451	404	203
Huntington Beach	Orange	1,549	694	267
Oak Park	Sacramento	1,104	497	293
Ojai	Ventura	591	478	166
Olive	Orange	176	335	278
Placentia§	Orange	623	311	...
Atwood	Orange	...	...	...
Sunland-Tujunga	Los Angeles	3,359	432	201
Venice-Culver City	Los Angeles	14,978	515	139
Walnut Grove‖	Los Angeles	62	...	...
Wilmar	Los Angeles	3,062	325	190
Los Alamitos	Orange	215	527	172
Stanton	Orange	209	229	228

*An average of 4 consumers is served by each customer's service connection.
†Industrial use eliminated.
‡Unmetered supply; consumption determined from several tests.
§Part of supply unmetered.
‖New system averages not established.

the well to determine the power, in kilowatt hours, required to raise 100 cu. ft. of water 100 ft.

The second check is the reading of power and water meters by the field operator on his daily rounds.

The third check immediately follows any variation in the consumption of power per 100 cu. ft. of water produced. This is the field check by engineers of the construction department of the efficiency of all the pumping units at the plant.

Wear or corrosion is immediately evident from one or all of these checks. During the war, when materials were difficult to obtain these checks became very important; they were the insurance against failure of the primary supply of water. The importance of this insurance lies in the fact that the total number of customers served during the last five years has increased nearly 10 per cent, whereas the available capacity of turbine pump production has decreased slightly. The result is that on maximum days every piece of equipment is in operation to meet the maximum hour.

Maintenance Program

Both the construction department and the engineering department work in close co-ordination on all phases of the company's operations. Seventeen years of co-operation has built up mutual understanding of the problems of each department. The result has been the adoption of certain theories and policies regarding design, maintenance and repair and operation.

The turbine pump maintenance program attempts to keep equipment in the best operating condition possible. Experience has shown that this policy can be carried out by pulling pumps for overhaul every 2, 3, 4 or 5 years.

Two-year schedule. Where the pumps are operating in "bad water," containing iron and sulfur organisms, or iron and manganese accompanied by hydrogen sulfide, or in wells which produce large quantities of sand, with the pumps operating under heavy-duty conditions—that is, for long hours every day in the year—a 2-year overhaul interval is scheduled.

Three-year schedule. No pump in "bad water" is permitted to operate beyond a 3-year period regardless of the number of hours which it may have operated. Normally, heavy-duty units are overhauled on a 3-year period, even in good quality waters.

Four-year schedule. Pumps operating under relatively light duty and under "fair" water quality conditions are overhauled every 4 years.

Five-year schedule. Regardless of the characteristics of the water or the conditions of pump operation, no pump is permitted to run more than 5 years without an overhaul.

Extent of Repair and Replacement

When pumps are pulled from the well they are completely disassembled in the field or in the pump company's shop. Each part is subject to inspection by a trained engineer.

Generally, the inspections reveal the need for the following repairs:

Bowls

The top and bottom bearings or bushings are replaced. The replacement of main bearing housings or castings, however, is seldom needed. New wear and seal rings

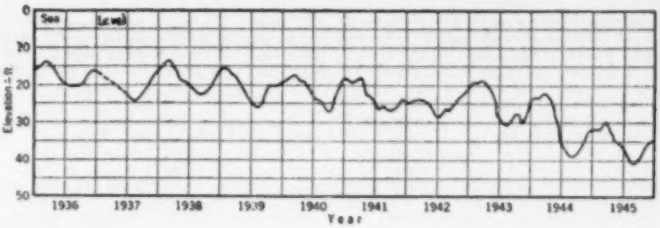

Fig. 3. Variations in Static Water Level of a Well

are nearly always installed, on both intermediate bowl castings and impellers. Intermediate bowl castings are replaced when not sufficient metal remains to permit machining for the installation of new rings or when excessive corrosion or sand cutting is apparent; and impellers are replaced for the same reasons. A new stainless steel pump shaft is installed only if injured in disassembly or when there is a change in basic bowl design.

Column

The most serious pump column replacement problem occurs with that portion of

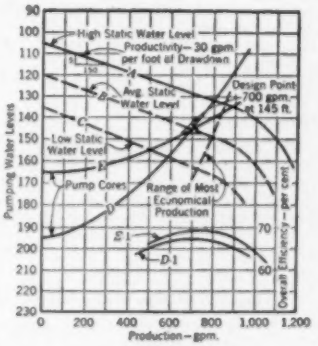

Fig. 4. Design Conditions for a Well

the column immediately above the pump bowls. This section is subject to more corrosion, sand cutting and wear of all sorts than any other, probably as a result of some turbulence in the water as it leaves the bowls. The first joint of casing above the bowls generally needs replacing or "pup jointing," that is the replacement of a portion of the casing with new pipe. Pup jointing is accomplished by cutting off the corroded section and using a pipe coupling to install a short piece of pipe that makes up the required length. The oil tubing often shows results of corrosion both inside and outside, between the static and pumping water levels. This occurs because water alternately will rise within the oil tube to the static water level of the well and drain out to the pumping water level during operation. The line shaft also becomes corroded within this range and must be turned end for end and reground at the bearing points on each overhaul. Often individual pieces of shaft can be shifted within the assembly to overcome wear or corrosion. The line shaft bearings or tubing couplings are all sized, and are replaced if they show wear of 0.012 in.

Motors

For each overhaul, motors are taken to the company's electric shop, where they are cleaned, reinsulated, and have their bearings checked, so that the motor goes back as nearly as possible in perfect condition.

Manufacturers' Service

Even under emergency conditions, working around the clock, it requires two or three days to pull, tear down, inspect, repair and reinstall a deep-well turbine pump. Failures of pumping equipment occurring on peak days or even peak months can be serious. It is the general practice in designing water supplies utilizing ground-water reservoirs to have primary capacity to meet at least the maximum day. Maximum hours can be taken care of by elevated storage.

During the war, it was nearly impossible to obtain sufficient materials to keep production facilities ahead of demand. It seems even more difficult now. The rate of population growth in Southern California is greater than ever before. It is, therefore, highly important to keep equipment in the best possible condition.

Emergencies, however, do occur. It is then necessary to move, and to move quickly. The company has always required that repairs be made by the manufacturer. Consequently, deep-well pumping equipment is purchased only from those manufacturers who are prepared to render immediate service. Only three manufacturers who can meet this specification have yet been found.

Choice of Pump

As is true in any arid country, Southern California has cycles of rainfall. These cycles recur from season to season and from year to year. The result is that the underground storage, as reflected in static water levels, varies both seasonally and by cycles of years. The season-to-season cycle indicates a range—often as much as 50 ft. —from a high in February and March to a low in September and October. The general conditions are illustrated in Fig. 3, which shows the variation in static water levels for a 10-year period on one company well.

Various water-bearing formations, whether Recent, Pleistocene or Pliocene, show different productivities. This productivity can be rated as the production volume in gallons per minute per foot of drawdown, and is the slope of Curve A, Fig. 4. The most economical production is always on the straight line portion of the curve, a short distance before the accelerated downward slope begins. No pump is ever chosen with a capacity greater than the most economical production of the well, as this factor seldom coincides with the

maximum efficiency of the pump. Figure 4 shows the design conditions of a recent well. The well was completed in the high static water level period and drawdown Curve A was obtained from test. Curves B, the average static water level and C, the low static water level, have been estimated from experience. Curves D and E are those submitted by two manufacturers for head capacity performance of a turbine. Curves D-1 and E-1 are the efficiency curves (ratio of power input at the meter to theoretical power required) and include all losses incurred in the motor, line shaft and bowls, and within the pump by water friction. Both performance curves were submitted by pump manufacturers to meet the design point.

It is interesting to note that turbine pumps are sold and purchased to meet one design point. This practice, promoted by the California Pump Assn., has been followed for years. The association has set certain standards of manufacture and fabrication and, for the sake of uniformity, a pump with a given head capacity and a given column length will be sold by all manufacturers at nearly the same price. Price, therefore, is not the controlling factor.

Even though its efficiency was less at the design point, pump D was chosen for the well because: (1) Pump E, at high water level, would operate below the range of most economical production; (2) the head capacity curve of D more nearly follows the range of the most economical production; and (3) Pump D produces more water when it is needed in summer low-water period.

A new condition has recently been imposed and influences the final choice of the bowl assembly. The Southern California Edison Co., which is now producing a 50-cycle alternating current, proposes to change to 60-cycles. This change will require the complete redesigning of bowls in a large number of turbine pumps, and to meet it, all pumps that will be purchased hereafter must be designed to operate on 60 cycles, but with enough additional stages in the pump bowls to operate temporarily on 50 cycles. This will provide for a minimum of changes in the pump and prepare for making the change with all possible speed.

The company purchases the complete unit installed in the well and ready to operate when electrical and pipe connections are made. The responsibility for individual parts of the units rests entirely with the one manufacturer, who is required to guarantee not only the pump but the motor he furnishes with it. The efficiency test following the purchase is for over-all efficiency of the complete unit.

Specifications

The standard specifications provide for the majority of operating conditions, although special conditions, already mentioned, at times require revision of the standards. Generally, the specifications are as follows:

Bowls

All bowl castings, including top and bottom bearing housings, shall be of the best grade iron used by the manufacturer. The impellers shall be of bronze containing 85-88 per cent copper, 5-10 per cent tin and 2-5 per cent zinc, and may have 5 per cent lead if the same bronze is used for both impellers and line-shaft bearings. They shall be machined so that no rough surfaces are in contact with the water. The pump shaft shall be of stainless steel. The suction shall be 10 ft. of standard pipe with a standard "Greene" strainer.

Pump Column Assembly

The line shaft shall be of cold-rolled steel with surfaces polished and shall be in 10-ft. lengths joined with couplings to permit butting of the shaft within the coupling. The oil tubing shall be in 5-ft. lengths joined with bronze guide bearings to provide a bearing at 5 ft. intervals on the line shaft. The eduction pipe shall be of standard weight pipe, joined in 10-ft. lengths. Spider guides shall be installed within the column at the points indicated on the well survey diagram.

Design Point

A performance curve of the proposed pump shall be submitted, indicating the performance of the pump from shut-off to its point of cavitation and showing the over-all efficiency curve. This efficiency curve shall show the guaranteed field performance of the pump as installed, and shall be computed by relating the power of input to the unit to the theoretical water horsepower.

Pump Head

The pump head shall be the heaviest casting constructed by the manufacturer to receive the motor required for the pump, have a discharge nipple of the same diameter as the pump column, and be at least 2 ft. long.

Motor

The motor shall be of such size that at no point on the performance curve will the rated horsepower of the motor be exceeded. The motor shall be a 440-v., 50-cycle, 3-phase, vertical, hollow-shaft motor. It shall be designed to receive an adequate thrust bearing.

Manufacturers' Specifications

The manufacturer shall submit complete manufacturing specifications which show the sizes of various parts of the column and the number of stages in the bowls. The speed of operation of the motor shall also be given, as well as the name of its maker.

The value of these specifications has been proved through extensive use. They standardize and simplify the problems of selection and maintenance of deep-well pumps.

DISCUSSION—T. E. LARSON

Chemist, Illinois State Water Survey, Urbana, Ill.

Corrosion experiences with deep well turbine pumps may or may not be considered serious, depending on the local physical conditions and the maintenance care provided. The economics of proper maintenance sometimes permits a $400 replacement at a 100-ft. setting biennially, with no regard to excessive corrosion rates, or may necessitate a $6,000 expenditure to pull a pump at a 600-ft. setting and replace column pipe, shaft and shaft tube.

Galvanic Action

The ordinary galvanic attack is aggravated if two galvanic cells are set up in series in the installation. Such a situation exists if bronze impellers are used with cast-iron bowls and copper-alloy bearing-retainers are used with a water-lubricated steel shaft. In oil-lubricated pumps, the galvanic series is created if bronze impellers are used with cast-iron bowls and water is permitted to enter the enclosure tube above the bowls and to come in contact with the bronze bearings and steel shaft. It is obvious in these situations that current will flow from the iron impeller seats through the water to the bronze impellers and up the shaft to the bearings. At this point the current will leave the shaft and flow through the water to the bearing retainers or to the bearings and down the column pipe or enclosure tube to the bowls. A vicious cycle of galvanic action can be set up in this manner.

Water-Line Corrosion

Water-line corrosion is usually due to the existence of an "oxygen concentration cell" near the water line on the outside of the column pipe, and is adequately described in many texts.

Carbon Dioxide Corrosion

Carbon dioxide corrosion takes place at the high-pressure points in the pump bowls and between the column pipe and shaft tube. It causes noticeable pitting in the bowls, on the column pipe and shaft tube just above the bowls, and, to a lesser extent, just above the spiders.

A possible explanation of this type of corrosion is that it is caused by the release of gas bubbles in the water at the low-pressure points on the underside of the impellers and possibly at the entrance to the suction pipe. This can happen, particularly if rough edges are present. The gas is composed of nitrogen, water vapor and carbon dioxide, and can be expected in any ground water under artesian pressure. When formed, the gas bubbles pass through the turbine and column pipe and undergo changes in volume due to the changes in pressure that take place. They are carried through the pump into the column pipe.

A rapid increase in pressure gives the carbon dioxide a higher solution potential and, as it dissolves, the water film on the surface of each bubble becomes excessively acid through the formation of carbonic acid. As the gas bubble with its acidic surface film passes over metal, corrosive action takes place.

Stray Currents

Stray currents are known to exist at many installations. To what extent they may damage the pump will depend on whether the polarity at any point enhances or inhibits corrosion.

Prevention of Corrosion

Prevention of corrosion depends largely on the type of installation, the corrosion expected or encountered and the economics involved. Consideration of the savings effected by preventive methods should include the power saved by maintained pump efficiency and the trouble and cost of pulling the pump, as well as the cost of actual replacements.

RATING AND SAMPLING WELLS BY AN IMPROVED METHOD

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It is oft-times desired and of importance to ascertain the quantity and quality of water yielded by an individual driven well connected to other wells of a water system. Experience has shown that analyses of samples of water taken from individual wells by means of a hand pitcher-pump give false and meaningless results, especially in relation to the iron content. Likewise the yield of an individual well by means of separate pumping furnishes but little if any information as to the yield of the individual well when ganged together into a common system.

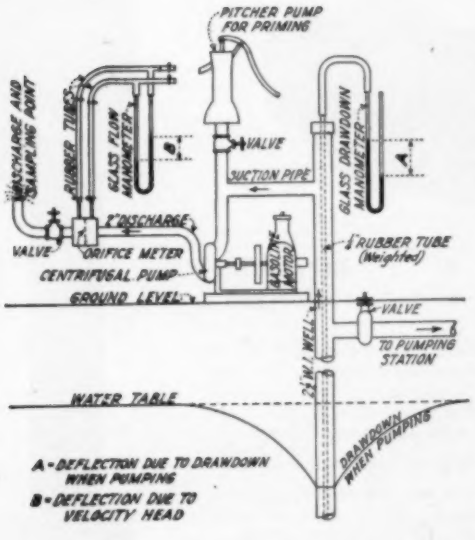
The writer's firm was engaged to investigate a water supply from about 90 driven wells. During the course of the work it became desirable to determine the yield of each individual well and the iron content of the water from each individual well under normal operating conditions. This was done by a device which we have called a Well Rater and Sampler. The device (see cut) was connected to the top of the well by a 2½ inch wrought iron pipe about 2½ feet long. At this point a 1¼ inch centrifugal pump was connected by the proper fittings and discharged through a 2 inch pipe. On the suction pipe a hand pump was attached to prime the pump. A 2 inch orifice flow meter was inserted in the discharge line and by means of a manometer the rate of flow was determined. The amount of the draw-down of the well, when connected to the well field, was determined by means of a mercury U tube connected to a small tube attached to the well cap, the tube extending into the well to a depth sufficiently great so that the end was at all times below the level of the water-table outside of the well.

Before the Well Rater and Sampler was connected to the well the permanently installed valve on the suction line was closed. After the device was connected this valve was opened and the well was observed under actual working conditions—i.e., while it was being pumped along with the other wells by the large pump in the pumping station. The drawdown was revealed by the reading of the manometer connected to the tube in the well and recorded. Thereafter, the permanently installed valve was closed and the centrifugal pump started, the rate of pumping being controlled by a valve on the discharge line. As the discharge increased the drawdown increased, thus producing a deflection on the manometer. When the manometer reading was the same as that already observed under the actual working conditions, as just described, the output of the well was assumed to be the same. The quantity being pumped was then determined by observing the deflection of the flow manometer on the pump discharge line. The results represented the actual amount of water that the well was contributing from the field as a whole when under *actual* pumping conditions. Samples of water for analyses, then taken at the point of discharge, were considered truly representative samples.

By careful operation of the valve at the discharge end of the pipe the yield of the well was brought gradually up to the original yield at the beginning of pumping. Thereby higher velocities than usual or ordinary in the pipe well were provided. Any excess velocities would, of course, free scale, rust and other matter and give false samples. The flow manometer in this particular instance was connected to the 2 inch orifice flow meter. [The liquid used to determine the differential pressure can be of any specific gravity desired depending upon the rate of flow to be measured. The most common is mercury for high flows and carbon tetrachloride, Specific Gravity 1.60, for low flows.]

One side of the mercury U tube was connected to the tube in the well and filled with water from the surface of the mercury to the water level in the well, care being taken to remove all air. The other side of the U tube was left open to the atmosphere.

*Whitman and Howard, Engs., Boston, Mass.



WELL RATER AND SAMPLER

The Hook-Up of the Well Rater and Sampler

A Specific Case

The following specific example will serve as an illustration. After the Well Rater and Sampler had been properly set up and connected to a well the mercury U tube was connected to the tube in the well. There was an initial deflection of mercury of 3 inches which represented a water column of 40½ inches, the distance from the water table to the mercury surface of the U tube. After an equilibrium had been reached the well was connected to the field and the mercury in the U tube deflected an additional amount corresponding in general to the distance the water table dropped outside of the well and specifically to the drop in pressure in the well. In this case the total deflection was 4¼ inches or a difference in deflection of 1¼ inches which equal 17 inches of water as the drawn down within the well.

The well was then shut off from the other wells and the small test pump started. The discharge valve on the pump was then opened slowly, increasing the yield of the well until the drawdown deflection of mercury showed 4¼ inches. After this point was reached the flow manometer was observed to have a deflection of 1⅝ inches of mercury which on this meter represented a flow of 20.1 gallons per minute.

The yield of the various wells in relation to the drawdown was plotted on arithmetic paper and the yield of each well was found to be directly proportional to its drawdown. The yield of the various wells varied from 1 to 25 gallons per minute and the drawdown varied from 5½ to 26 inches.

This device has been made use of in installing new driven well fields. By its use we have been able to predict reasonably well the draw down or vacuum to be expected in a system of driven wells and to eliminate uneconomic wells, which have a low yield in relation to the drawdown. Also with open end wells it has been possible to determine at what yield a well will throw sand sufficiently to result in filling up by sand. The equipment will probably be found to have other uses also.

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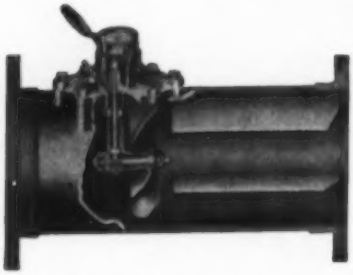

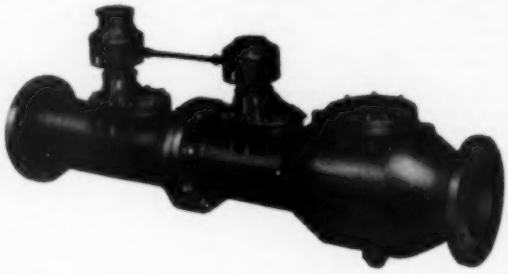

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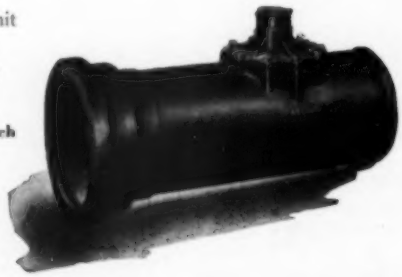

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CENTRIFUGAL PUMP PECULIARITIES

By ROBERT W. ANGUS
Consulting Engineer, Toronto, Ont.

PRACTICALLY all pumping units now being installed in water works plants are composed of centrifugal pumps driven by electric motors, steam turbines or internal combustion engines, and few plants today use reciprocating pumps. Experience with centrifugal pumps has now been sufficiently extensive for operators to know many of their peculiarities; yet there are features connected with their use that are worthy of review.

Setting of Pump

The setting of the pump is perhaps one of the most important matters, as it may easily account for any later defective operation. It is, of course, well known that the pump should be set as little above the well level as possible, and it is usually preferable to have it below this level (except for the difficulty of unwatering it) if for no better reason than ease of priming and freedom from the foot valves on the suction line. That the pump is unduly sensitive to suction conditions is a matter of general experience, and long and crooked suction piping is to be avoided.

The author has made tests on the effect of foot valves, which showed that resistance in these might cause a high vacuum at the suction flange of the pump and a corresponding decrease in discharge. [*Jour. AWWA*, **37**:70 (1945)]. High-suction vacuum naturally induces air leakage into the pump through the glands, and also releases whatever air there is in the water being pumped. In order to investigate the effect of air leakage, a number of experiments were run on a 4-in. pump, in which various volumes of air were admitted into the suction pipe after carefully sealing the glands so that leakage was practically stopped there.

In this pump the percentage decrease in discharge at a given head was roughly proportional to the percentage, by volume, of air admitted, so long as the latter remained below about 1.5 per cent (see Fig. 1); but thereafter the water discharge fell off very rapidly until there was a decreased discharge of over 40 per cent when 4 per cent of air, by volume, was admitted. This merely confirms the well-known fact that at low suction lifts, and consequently low air inlet leakage, the exact elevation of the pump is not so important. There is a critical elevation for each pump and condition, however, and if this is exceeded the loss of water increases at a rapid rate. Clearly the height of the pump above the well level should be kept substantially below this critical elevation.

Specific Speed

Fortunately the importance of this matter is now recognized by the pump builders, and they have found that for each head, discharge and speed there is a maximum height above the well at which each pump should be set. These three quantities are combined in a formula for "specific speed" which is defined by:

$$\text{Specific speed} = N_s = \frac{N\sqrt{G}}{H^{0.75}}$$

where N is the revolutions per minute, G is the discharge in U. S. gallons per minute and H is the head in feet.

Pump builders have co-operated in connecting the specific speed and head with the maximum allowable suction lift, basing their conclusions on laboratory tests and on experience with pumps which they have installed. Through the Hydraulic Institute they have given these maximum elevations in the form of diagrams, separate ones being used for single-entry pumps, for double-suction single-stage pumps, etc.

As an illustration, there are four double-suction single-stage raw water pumps at the Victoria Park pumping station, Toronto, Ont., rated at 24, 30, 48 and 60 mgd., respectively, all of them for 9-ft. suction lift and for a total head of 82 ft. The two larger pumps operate at 750 rpm., and if this speed had been adopted for all four pumps, their specific speeds and maximum suction lifts, including velocity head and friction in the suction pipe, would have been as shown below in the Institute's chart.

Size of pump, mgd. (U. S.)	24	30	48	60
Specific speed at 750 rpm	3545	3970	5010	5610
Maximum allowable suction lift, *ft*	18	15	5	..
Necessary suction pressure, *ft*	..	..	..	5
Specific speed at 500 rpm	..	..	3340	3749
Maximum allowable suction lift, *ft*	..	..	20	17

Since the velocity heads in the two larger pumps are 2.3 and 2.1 ft., respectively, and since friction must be allowed for, it is clear that, while there is a margin on the two smaller pumps when run at 750 rpm., the two largest pumps could not be run at this speed and had to be changed to 500 rpm., which is the next available speed.

Setting pumps too high not only causes them to lose capacity, but also means noisy operation and cavitation, which is frequently destructive. As the capacity of a pump at fixed speed is gradually increased by lowering the discharge pressure, a point is finally reached where the characteristic curve is nearly vertical, which point naturally corresponds to the limiting output of the pump. Cavitation and noise are present at such a discharge (and in its vicinity) and the higher the suction lift the lower this limiting output is. It is to avoid too close an approach to this point that the charts reproduced have been made. Noise in a pump operating near this limiting point may often be stopped by the admission of a very small volume of air to the suction pipe.

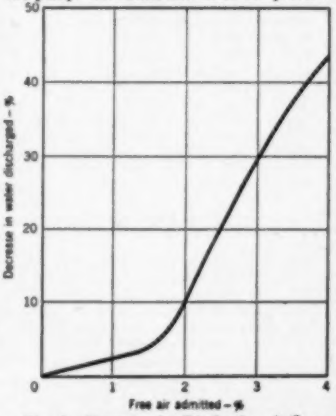


Fig. 1—Decrease in Discharge of Centrifugal Pump Due to Admission of Air Into Suction Pipe in Various Amounts.

[Ed. Note—Indeed an interesting and illuminating statement in view of the generally held misconception that cavitation, with its noise of pebbles or buckshot passing through the centrifugal casing, is due to air within the casing. On the contrary, it appears that the noise is due to partial vacuum within the casing which is relieved by admitting air.]

Power Failures and Water Hammer

Power failures on motor-driven centrifugal pumps present some problems. A check valve is usually placed on the line close to the pump, and if this acts slowly there is backward flow through the pump which reverses its direction of rotation unless specially prevented. If the check valve does act rapidly, however, water-hammer pressures are often excessive, resulting in damage to the plant. A number of cases of the latter have recently come to the author's attention.

Water hammer, contrary to a common belief, is also often dangerous in low-head pumping. The author made some tests on a 12-in. pump working against a 55-ft. static head, with a discharge line only about 350 ft. long, and recorded the pressures with a Crosby indicator with a 30-lb. spring. When the switch was opened the pressure drove the indicator pencil off the top of the drum, indicating a pressure of more than 60 psi., and the first pressure wave measurable showed 50 psi. or a 115-ft. rise. As stated, this was a short line and the pipe velocity was under 4 fps. However, in another case where the static head was 40 ft. and the line was over 2,000 ft. long, the pressure rose to 83 ft. with normal pipe velocity of slightly over 7 fps. In both cases the pressure rise was high enough to cause some anxiety, which was further aggravated in the first case by the noise and shock plainly observed at the pump, while in the second case there was *no* apparent shock on the system. In the first case, the maximum pressure rise occurred 2.6 seconds after cutting off the power, whereas it took 13.0 seconds in the latter case.

Short lines are sometimes more dangerous than long ones, because in the latter the water takes an appreciable time to slow down before coming backward, thereby giving the check valve time to close *gradually* and prevent any real reverse flow of the column. In short runs of pipe the water column reverses in much less time, as the above measurements show, and

actually *before* the check valve has had time to close. Thus the water gains a high backward velocity, suddenly closing the check valve with a slam, and producing high pressures. The maximum pressure rise, in feet, reaches about one hundred times the velocity of the water in the pipe at the time the valve suddenly closes.

Air Chambers vs. Properly Closing Check Valves

Sometimes an effort is made to decrease the danger by using an air chamber, but this is far from the best method and does little good unless the chamber is placed on the line near the pump and has a large short connection with the pipe. Air chambers connected to the line with a fairly long branch pipe are of little value and, of course, any virtue the device has will be lost unless there is a good volume of air in the chamber under normal conditions. A well-designed check valve, with a proper controlling mechanism which permits the greater part of the closure to be rapid and the latter part gradual, offers a good solution, and a number of such valves are now on the market. It is a fact that unless the pump is equipped with a heavy flywheel, as is sometimes the case, the pump will often run backward before the check valve closes, but, in general, the reverse speed is not over 20 per cent higher than normal running speed and is not dangerous from that standpoint.

In many installations reverse rotation of the unit causes little difficulty, but where sleeves are screwed on the shaft and pass through the packing gland, the builder usually makes the thread so that during pumping the tendency is to tighten the sleeve against the impeller. If the glands are tight, then when the pump runs backward the sleeves may unscrew, and cases are not unknown where the pump has been damaged by breaking off the bearing bracket. With the sleeve unscrewed the impeller is not properly restrained from moving along the shaft and this further increases the danger of damage.

Pumping Plants

There are some unusual installations, one of which may be mentioned as an illustration (see Fig. 2). A very large size pump with a vertical shaft was set up with 40 ft. of vertical discharge pipe followed by a long horizontal line. The pump was nearly 20 ft. below the water in the well so that no priming was required, but there were nearly 800 ft. of horizontal suction (intake) pipe in which the velocity was 5.9 fps. at steady operation. It was inconvenient to place the discharge valve close to the pump, and it was actually installed just beyond where the horizontal and vertical pipes joined. There was no valve of any kind on the suction side. In the installation shown diagrammatically in Fig. 2 the distance (A) was nearly 20 ft.

Following common practice, the motor switch was thrown in with the discharge valve closed, and just as the valve started to open when the pump was up to speed, a pressure shock cracked the pump casing. This might have been foreseen, because, when the pump was shut down with discharge valve closed, water in the vertical discharge pipe quickly fell to the well level, leaving a space filled with air in the discharge line between the well level and the valve. On starting the pump against the closed valve the air was compressed to about discharge pressure, and as the valve

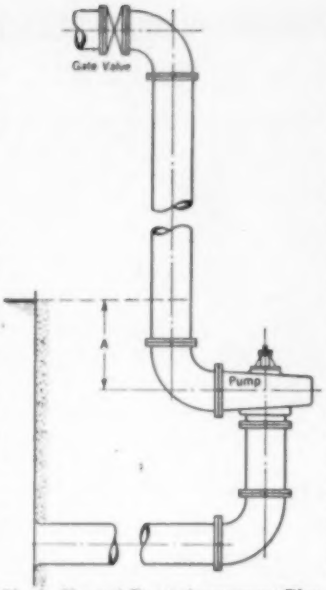


Fig. 2—Unusual Pump Arrangement That Resulted in Heavy Water Hammer Pressures Until Vacuum Pump Was Installed to Exhaust Air from Discharge Pip and Fill It with Water Before Starting Up.

began to open the air rushed out of line, allowing the water to reach full velocity in the vertical pipe. As the front of this water column reached the partly open valve the velocity was largely extinguished and a heavy water hammer pressure resulted. Since it would have been very expensive to lower the discharge valve, the only remedy was to put in a vacuum pump and exhaust the air, in order to fill the line with water before starting up.

The long horizontal suction pipe greatly complicated the problem, for the water would be drawn from the pump end of it before the column could be sufficiently accelerated to supply the demand, and water hammer pressures would be set up in the pump from this cause. A well should always be close to the pump (or the pump located close to the well) to supply the water demanded while that in the intake line is being brought up to running velocity.

Where several pumps are to work in parallel on the same line, their characteristics should be given careful consideration, otherwise their actual output may fall far short of the sum of their individual deliveries. In Fig. 3 are shown the characteristic curves of two actual pumps, A and B, in the same station, their individual normal operating points being indicated by G and J. If these two pumps are thrown on the line at one time their combined characteristic is shown by the plain curve found by adding the discharges of A and B at the same pressure in each case. The static head, corresponding to the tank level, is shown at D, and the curve C indicates the dynamic head to be pumped against, the vertical distance between D and C corresponding to the resistance loss for the corresponding discharge.

It is to be noted that, while the sum of the separate discharges at rated heads is 180 per cent of the discharge of the larger pump, yet when both are put on the line at the same time the combined discharge at F is only 133 per cent of that of the larger pump, because of the increased pressure. Where the individual characteristic curves are flat this decrease is greater than with steep curves, because a slight increase in pressure corresponds to a large decrease in discharge, but, on the other hand, a pump with steep characteristic at the normal output point has a rapid decrease in pressure for discharge above normal, so that other circumstances must be taken into account.

Propeller-type Pumps For Low Head Duty

Propeller-type pumps are being introduced to a fairly large extent to cover the field where the head is low and the discharge is large. Centrifugal pumps are used in this service, but must be run at slow speed and involve the use of a speed reducer or an expensive and bulky motor, whereas the propeller-type pump is relatively small and may be run at the speed of the ordinary motor. Its field of service is for drainage and sewage work and for pumping water up to water works filters, but the same type of pump is also used for deep wells because its small diameter enables it to be fitted inside ordinary pipe casing.

As so far developed, these pumps have the undesirable characteristic forms of curves, where the head and power at zero discharge and at full speed are higher than, and sometimes twice as high as, the corresponding quantities at rated discharge, and the curves generally have the reversed form. Usually the pressure is not high enough to cause any trouble, but the high power means a correspondingly large torque on the motor, which the latter may not be able to produce. Therefore either special starting devices are necessary or the pump must not be brought up to speed with a closed discharge valve. With a check valve on the discharge and an open gate valve, the head developed cannot exceed the back pressure from the line, and this is one effective method of starting that is used. Also a bypass is sometimes arranged around the pump, having a valve which may be opened so as to allow some water to flow through the pump, thus avoiding the zero discharge condition.

Deep Well Pumps

Deep well pumps must be as small in diameter as possible so that they will fit into the well casing, and for that reason they approach the axial-flow type with relatively small head per stage, although the high motor speeds somewhat compensate for this. However, for the higher heads many stages are used, and guide vanes are placed between each pair of impellers. Both open and closed impellers are used, but the latter are the more common. The driving motor is often placed at ground level, and the pump is usually submerged in the well water to avoid priming, but since these wells are sometimes 200 ft. deep, the driving shaft is long and has to be guided at various points at which rubber-lined guide bearings are often used with water lubrication.

Some builders, such as Byron Jackson, couple the motor to the shaft as in ordinary installations, and the motor is there-

fore submerged in the well water and often is actually located *below* the pump.

Power failures on these pumps, where the vertical pipe is long, result in back-flow through the pump and cause the pump to run in the reverse direction, but most pumps of this type are designed to withstand this without damage. However, the surges in the pipe during reverse flow of the water affect the pressures in the pump to such a degree that open impellers may be forced to pound down against the casing and wear somewhat rapidly. Some builders arrange a ratchet or a brake on the pump shaft to prevent the latter from turning backwards.

Where both motor and pump are submerged and completely enclosed, it is difficult to tell whether the electrical connections are such that the pump is running backwards, and in three-phase circuits it is well known that the connection for forward rotation can only be found by trial. If it is impossible to tell by visual inspection whether the pump runs backwards or not, about all that can be done is to read the discharge gage pressure; if this pressure at no discharge is very much below the normal working head on the pump, the motor and pump are, in all probability, running backwards.

Miscellany and Summary

Noise accompanied by cavitation damage in pumps is frequent if the pumps are set high above intake water level. The same results are noticed when the discharge is low, due to either reduced speed or increased head. Foot valves and strainers on the suction inlets may also induce these troubles and should be avoided where possible.

Occasionally cavitation has seriously damaged impellers in less than two years but it is often quite possible to build up the damaged places and completely restore delivery and efficiency. Frequent inspection is necessary. In one case an impeller was covered with a thick coating of slimy material which decreased the capacity considerably. This pump was used partly for refilling the coagulating basins and was designed for about a 26-ft. head. When the water was low in the well its capacity fell off. A number of operators have found that high suction lift decreases output.

Occasionally, noise in the motor gives the impression that the pump is at fault.

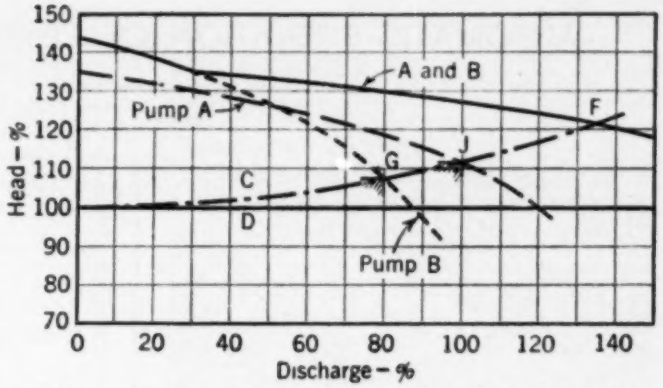


Fig. 3—Characteristic Curves of Two Pumps Operating in Parallel in the Same Station and Discharging Through a Common Header.

Noise in the pump may frequently be greatly reduced by admitting air to the suction side, but this must be carefully controlled, as the capacity falls off rapidly as the admitted air increases. In some tests of one pump 4 per cent of air by volume reduced the capacity nearly 40 per cent.

Putting several pumps in parallel on the same line decreases the capacity of each in a way that varies with the pump characteristics. There is, of course, increased friction in the discharge lines when more water is put through; and, as this increases the head on the pump, there will be a corresponding decrease in discharge.

There is an objection to a common suction header for several pumps, as air may leak through the glands on the idle pumps and interfere with those running. The suction pipe of each pump should run direct to the well as an independent line.

Water hammer and pressure surges are common on lines having centrifugal pumps. Frequently a pressure surge lasting a short time occurs when a pump is put into service. Power failures cause extensive pressure oscillations which have been greatly reduced by special types of check valves with a controlled time of closure. Air chambers are not as satisfactory.

The shape of the profile of the discharge main greatly affects water hammer in the line after power failure. In the 48-in. line in Toronto there is a point where the pressure drops much below atmospheric when power fails, and observations agree with the theory that the water column actually separates at this point. The use of a specially controlled check valve with 4-in. bypass has prevented a dangerous pressure rise when the columns re-unite; the purpose of the bypass is to fill enough of the space with water before the velocity of the returning column from the reservoir becomes high enough to cause damage when it re-unites with the part of the column at the pump end. The actual maximum pressure rise is only about 35 per cent and is reached in about 50 seconds where the pipe velocity is low. The pump is about 4,300 ft. from the breaking point of the column and nearly 8 mi. from the reservoir.

Reversal of pumps after power failure has often been observed, but with no harmful results to the motors. A case has been reported, however, of an engine driving a centrifugal pump being damaged by running backward.

Aside from ordinary wear, the mechanical difficulties with pumps are not serious. Some pumps have excessive end thrust, and where this is taken up by ball bearings, the latter run hot. Over-lubrication is known to increase the heating. Bearings are easily cooled with a small stream of water. Hydraulic balancing of end thrust is satisfactory where the pump is running under normal conditions.

HOW TO BEND PIPES

TO bend steel pipes, fill with dry sand and plug the ends. Heat to a red heat in the localities to be bent and then bend. *Be sure that the sand is dry.* Where bends are slight, it is often unnecessary to use sand. The object of sand is simply to keep the sides of the pipe from collapsing, or to prevent reduction of flow area. If wet sand is used, and if the ends are plugged, the pipe may burst when heated, due to the steam pressure generated.

For the smaller pipes instead of sand resin is good. There is, however, a "right way" and possibly several wrong ways to use resin. An example of a wrong way was recently brought to my attention where the mechanic filled the pipe with resin, plugged the ends, and heated the pipe at the place where he wanted to bend it. He watched for a "red heat" just as he would had he filled the pipe with sand. The result was a violent explosion.

To use resin correctly, pour it into the pipe molten and allow it to cool and harden. As soon as the resin is hard, bend the pipe cold. Don't heat it. Then after the pipe is bent, heat the pipe all over sufficiently to melt and remove the resin.

Equal results may be secured by using lead instead of resin. I have been told that on cold days water has been used also.

Many excellent mechanical devices are on the market for bending pipe. To bend large, stiff pipe slightly (and inexpensively), there is nothing handier or more efficient, in my judgment, than a hydraulic pipe bender driven by a hand pump.

AUTOMATIC OPERATION OF CENTRIFUGAL PUMPS

By W. D. HAENTJENS
Engineer Barrett, Haentjens & Co., Hazleton, Pa.

THE purpose of automatic pumping is, in most cases, the achievement of more economical operation through the elimination of an attendant. At times, the purpose is greater safety of operation.

In the simplest case of automatic pump control, that is, pumps operating with a positive head on the suction, no special equipment except float switches and automatic starters is required.

Pumps operating with a suction lift can be equipped with a footvalve which keeps the pump filled with water between runs. Automatic control here can be the same as that for pumps operating with a head on the suction. However, the use of a footvalve results in somewhat unreliable control. There are several objections to the use of a footvalve; (1) the pump is unprotected from water-hammer and failure of the pump casing may result; (2) the footvalve may leak, thus leaving the pump without water. When the pump is started, damage would undoubtedly result to the pump; (3) friction in the footvalve results in an increased suction lift.

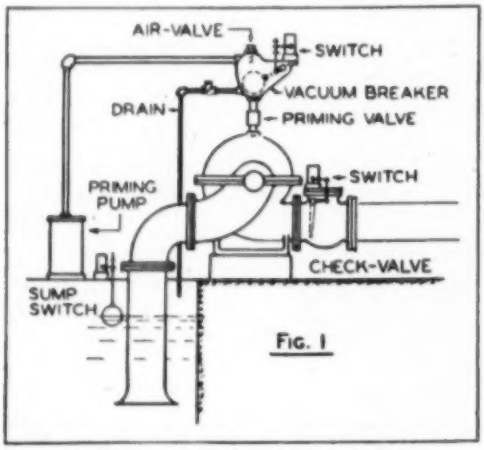
Components of Automatic Control Systems

A brief description of the operation of a few of the components of an automatic control system (Fig. 1) is perhaps in order here.

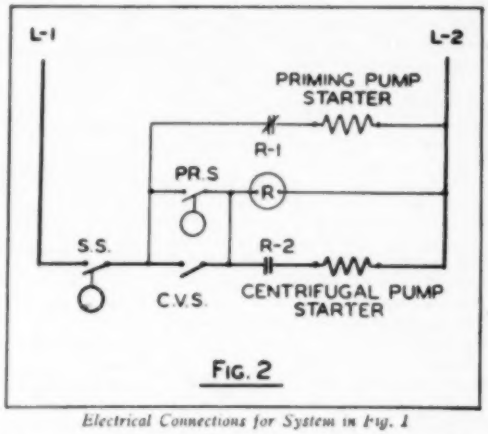
I. Check Valve with Switch—The check value is always placed on the discharge end of the pump. To the flap of this valve is attached a switch. This switch may be one such as a lever-operated contact switch or a Mercoid switch. The switch, normally open, closes when the pump goes into operation and remains closed as long as the pump is discharging water.

II. Priming Valve—This is an automatic valve which is mounted on the top of the centrifugal pump casing. It permits the passage of air through it during the priming operation, but closes when water at the operating pump pressure attempts to flow through it. It remains closed only so long as the pump is in operation.

III. Vacuum Breaker with Priming Switch—This unit is mounted so as to be higher than the priming valve. Air exhausted by the priming pump passes through the pump casing, then through the priming valve and vacuum breaker to the priming pump. The action of the vacuum breaker is: (1) to prevent water from entering the priming pump, (2) to actuate the priming switch when priming is completed, (3) to automatically drain and prepare for a new priming cycle once the pump is in operation. The priming switch is normally open. When the water enters the vacuum breaker chamber, the float rises and simultaneously closes the switch and opens an air valve. Air, entering through this valve, breaks the vacuum and permits the water to drain out of the chamber.



Components of an Automatic Control System



Electrical Connections for System in Fig. 1

For safe and dependable control of pumps operating with a suction lift, a vacuum pump is used. Reduced pressure produced by the vacuum pump permits the water to rise from the sump into the pump, filling the pump casing and float chamber. As the float in the chamber rises, it operates the priming switch which is connected with the starting circuit of the centrifugal pump motor. Shutting down of the priming pump is also accomplished at the same instant.

In its simplest form these arrangements are shown diagrammatically in Figure 1. The check valve prevents the entrance of air during the priming period and arrests the back flow of water when the discharge line is filled and the pump stands idle. In the latter condition, the pump in starting must produce a pressure sufficiently great to open the main-line check valve against the full water column pressure. This fact makes priming difficult when there are air pockets in the suction line. The air from these pockets, when drawn into the pump, gathers around the impeller hub, causing the pump to lose suction and preventing it from building up sufficient pressure to start the flow of water through the check valve.

In order to remove this air, the pump must be stopped and allowed to remain idle sufficiently long for all the entrapped air to rise to the top of the pump casing. It can then be removed by the priming pump at the next priming attempt.

It is therefore evident that automatic control must provide for more than one start and for a delay between starts. Not only air pockets, but also air leaking through the stuffing boxes may destroy the prime. At the first start, water is forced into the water seal ring of the stuffing box. This stops or so greatly reduces the leakage that the pump will be properly primed after two or perhaps three priming attempts.

Should the seal water not stop the leakage, there may result a continuous starting and stopping of the priming pump and the centrifugal pump. Automatic control must therefore limit the number of starts to three or four. The justification for this feature was clearly illustrated by experience in early automatic installations. In one instance, one standard automatic starter for a squirrel cage motor made 450 starts from 1 p. m. Monday afternoon to 7 a. m. Tuesday morning, a total of 25 starts per hour for 18 hours. This starter was roasted.

The air leak may be so large that the priming pump cannot dispose of all the air leaking into the system and therefore cannot draw the water into the float-chamber. In that case, the priming pump will continue to run indefinitely. Thus in order to prevent damage to the priming pump or over-flowing of the sump, automatic control should limit the time required for priming.

Referring again to Figure 1, the priming valve is held open by the action of a spring and closed by water pressure when the pump begins to discharge water. As soon as this valve closes, the float-chamber begins to drain and its switch will open. It is

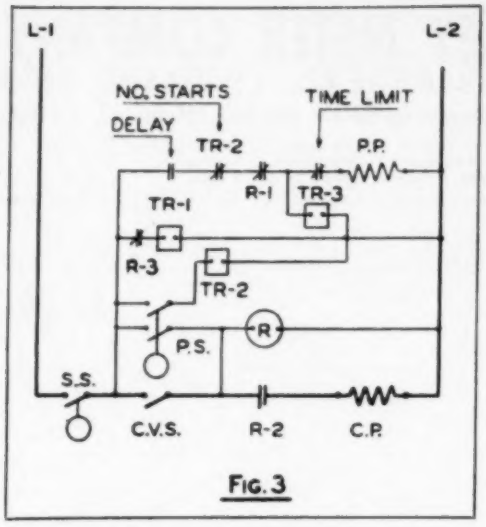


FIG. 3

The Time Relay Circuit for Preventing False Pump Starts

important that the float-chamber drain slowly so that sufficient time is permitted for the pump to build up speed and close the check valve switch before the priming switch opens. If this did not happen, the pump would immediately stop.

Electrical Circuits

Figure 2 shows the electrical connections for the above arrangement. When the water rises in the sump, closing the sump switch, current flows from Line 1, through the sump switch, SS, and the normally closed contact, R-1 of the relay R, thus energizing the priming pump starter. The priming pump begins operation. When priming is completed and the water rises into the priming chamber, the priming switch closes, energizing the retay R. This opens contact R-1, stopping the priming pump, and closes R-2, energizing the centrifugal pump starter. As the pump builds up speed and begins to discharge water, the check valve switch will shunt out the priming switch. The priming switch opens as the priming chamber drains. The importance of slow draining of the chamber can be readily understood here. The pump is now operating under protection on the check valve switch. Should the pump lose the water, the check valve switch will open, and the pump will stop. Relay R is no longer energized and R-2 drops out and R-1 closes again. If the sump switch is still closed, the priming cycle will be repeated.

Prevention of False Starts

To prevent too many false starts, a time relay is placed in the circuit, controlled by the vacuum breaker switch. The simplified wiring diagram, with other features, is shown in Figure 3. The timing action of this relay, TR-2 occurs only while the priming switch is closed. When a sufficient time for several priming attempts has elapsed, TR-2 opens.

The complete automatic action is exemplified by Figure 3. This action is as follows: When the water in the sump rises and closes the sump switch, SS, current flows from Line 1 through normally closed contact R-3 and time delay relay, TR-1, to Line 2. Then, TR-1 begins to time. After it has timed out, contact TR-1 closes and now permits current to flow through the normally closed contact TR-2 of time relay TR-2, then through the normally closed contact R-1 and through the normally closed contact TR-3 of time relay HR-3, to the priming pump starter which is now energized and starts the priming pump. When priming is completed and the priming chamber is filled, the priming switch PS closes and time relay TR-2 begins to time. At the same instant, relay R is energized, closing R-2 and opening R-3 and R-1, thus the centrifugal pump starter is energized and the pump starts; the priming pump stops and time relay TR-1 is reset.

Time relay TR-2 is cumulative, i.e., TR-2 opens only when the total time required for several normal starts is exceeded. Time limit relay, TR-3, is set for about 15 to 30 minutes to limit the time of operation of the priming pump during any one prime. Time delay relay, TR-1, has been reset by the opening of R-3 so that it will be able to delay a second priming attempt if the first was unsuccessful. Since large pumps are idle for as long as 30 seconds, TR-1 is set to trip in about one minute. If the pump is still not in operation after several priming attempts, time relay TR-2 locks out so that the system now completely ceases operation, but an alarm signal sounds either in the foreman's office or at any desired location. The system will not operate again until the trouble has been remedied and time relay, TR-2, reset by hand. Note, however, that all relays must automatically reset when the sump switch opens.

It is not the intention of this article to give a detailed description of the mechanical and electrical devices. These may vary considerably but they should provide the sequence of operation and protection outlined. Additional features such as pressure and vacuum regulator switches, water level indicators, thermostats on the pump main and thrust bearings, etc., may be added for greater safety. The most recent innovation is the use of electrodes in the sump in place of float switches.

PRESSURE IN POUNDS PER SQUARE INCH FOR DIFFERENT HEADS OF WATER

Head In Feet	0	1	2	3	4	5	6	7	8	9
0	....	.43	.87	1.30	1.73	2.16	2.60	3.03	3.46	3.90
10	4.33	4.76	5.20	5.63	6.06	6.50	6.93	7.36	7.79	8.23
20	8.66	9.09	9.53	9.96	10.39	10.83	11.26	11.69	12.12	12.56
30	12.99	13.42	13.86	14.29	14.72	15.16	15.59	16.02	16.45	16.89
40	17.32	17.75	18.19	18.62	19.05	19.49	19.92	20.35	20.78	21.22
50	21.65	22.08	22.52	22.95	23.38	23.82	24.25	24.68	25.11	25.55
60	25.98	26.41	26.85	27.28	27.71	28.15	28.58	29.01	29.44	29.88
70	30.31	30.74	31.18	31.61	32.04	32.48	32.91	33.34	33.77	34.21
80	34.64	35.07	35.51	35.94	36.37	36.81	37.24	37.67	38.10	38.54
90	38.97	39.40	39.84	40.27	40.70	41.14	41.57	42.00	42.44	42.87
100	43.30	43.74	44.17	44.60	45.03	45.47	45.90	46.33	46.77	47.20
110	47.63	48.07	48.50	48.93	49.36	49.80	50.23	50.66	51.10	51.53
120	51.96	52.40	52.83	53.26	53.69	54.13	54.56	54.99	55.43	55.86
130	56.29	56.73	57.16	57.59	58.02	58.46	58.89	59.32	59.76	60.20
140	60.62	61.06	61.49	61.92	62.35	62.79	63.22	63.65	64.09	64.52
150	64.95	65.39	65.82	66.25	66.69	67.12	67.55	67.98	68.42	68.85
160	69.28	69.72	70.15	70.58	71.02	71.45	71.88	72.31	72.75	73.18
170	73.61	74.05	74.48	74.91	75.35	75.78	76.21	76.64	77.08	77.51
180	77.94	78.38	78.81	79.24	79.68	80.11	80.54	80.97	81.41	81.84
190	82.27	82.71	83.14	83.57	84.01	84.43	84.87	85.30	85.74	86.17
200	86.60	87.04	87.47	87.90	88.33	88.77	89.20	89.63	90.07	90.50

METERS GAGES CONTROLLERS
for Sewage Treatment and Water Supply

BAILEY METER COMPANY

1072 IVANHOE RD., CLEVELAND, OHIO

Bailey Meter Company Limited, Montreal, Canada

Atlanta	Buffalo	Cincinnati	Detroit	Los Angeles	New York	San Francisco	St. Louis
Boston	Charlotte	Cleveland	Houston	Milwaukee	Philadelphia	Schenectady	St. Paul
	Chicago	Denver	Kansas City	New Orleans	Pittsburgh	Seattle	

STANDARD BAILEY REGISTERS

Standard Bailey Registers measure flow of sewage, industrial wastes, sludge, dirty water, or other liquids in open channels or in pipe lines. They also measure air flow, pH, liquid level in open and closed tanks and reservoirs, and other factors.

• • • **FOR OPEN CHANNELS—The Bailey Flume or Weir Meter** is simple and accurate. As shown in the illustration (right), it consists of a single float connected by a flexible cable to a sturdy indicating, recording and integrating mechanism which may be mounted on a panel board, a wall, or a column. It is adaptable to all open channel metering devices including flumes, weirs and nozzles and can be adjusted to any required operating range. Remote location is possible through use of a Bailey Telemeter, (see below). **Ask for Bulletin 62**

• • • **FOR PIPE LINES—The Bailey Open Float Type Meter** measures flow of sewage, sludge, dirty water, or other liquids in pipe lines using Venturi Tubes, flow nozzles, or eccentric orifices. It operates through a differential gearing and cam mechanism from floats which rest on the liquid surfaces in float tubes.

The Bailey Fluid Meter accurately measures flow of steam, liquids, and gases in pipe lines at high or low pressures. A Venturi Tube, flow nozzle, or orifice, is used as the differential producing device and the meter indicates, records and integrates on a Standard Bailey Register. This meter may also provide records of pressure, temperature or liquid level on the same chart. **Ask for Bulletin 301 B**

• • • **FOR LIQUID LEVEL**—Bailey Registers may be used in measuring liquid level in open tanks and reservoirs. Three methods are available to meet any requirement.

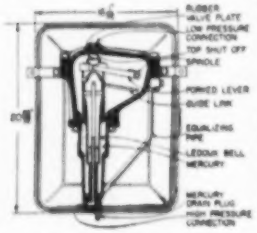
Open Float Method—(for location above liquid level). Has a minimum range of 0 to 5 inches of water and a maximum range of 0 to 60 feet of water.

Static Pressure Method—(for location below liquid level). Two types are available; mercury U-tube and float for minimum range of 0 to 50 inches of water, and maximum of 0 to 150 feet of water, and a helical coil for minimum range of 0 to 120 feet of water and maximum of 0 to 600 feet of water.

Bubbler System—For measuring level or specific gravity of corrosive liquids and of liquids with solids in suspension. **For information on Bailey Level Recorders ask for Bulletin 17-C**

• • • **FOR AIR FLOW—Bailey Air Meters** measure Air Flow in main lines and in individual lines to aeration tanks. The register used is similar in appearance to the Ledoux bell type (left) and the flow mechanism is designed to operate on a maximum differential pressure of eight inches of water. **Ask for Bulletin 301 B**

Air Flow from a rotary positive type blower can be measured accurately with a Bailey Electronic Type Recorder. Blower Shaft speed, measured by a tachometer is recorded in terms of Air Flow.

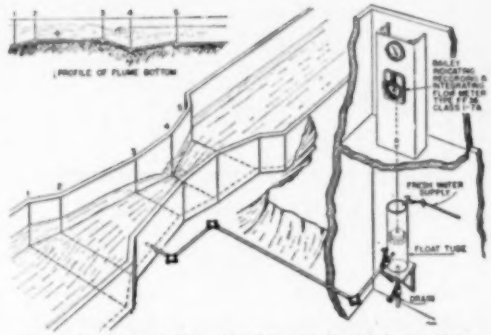


Ledoux Bell Flow Mechanism

BAILEY CONTROLLERS

Bailey Controllers utilize standard Bailey Instruments as the measurement source for automatic control of factors such as flow, ratio, pressure and liquid level. They operate by compressed air and are styled to match other Bailey Gages and Registers.

Bailey Control is fully automatic, dependable and exceptionally flexible,
Explained in Bulletin 17-C



Typical installation of Bailey Flow Meter for Parshall Venturi Flume

pH RECORDER

The Bailey Electronic pH Recorder accurately measures and, if desired, controls hydrogen ion concentration in a solution. The indicating and recording instrument is similar in appearance to a Standard Bailey Register. **Described in Bulletin 234**

Bailey Recorder—Controller

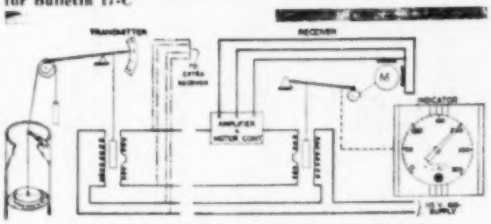
BAILEY TELEMETER

The Bailey Voltage Balance Electronic Telemeter is a quick, accurate means of transmitting position over distances. The measure of any factor which can be made to move the core of a small solenoid transformer may be indicated or recorded at a distant receiver. Multiple receivers may be connected to one transmitter. Several flow measurements can be totalized.

Bailey Large Dial Indicator

LARGE DIAL INDICATOR

Indicators containing the telemeter circuit receiving mechanism may be single or double face and may have 18, 24, or 30-inch dials. Numerals and indicating pointer are large for easy reading. **Ask for Bulletin 17-C**



Bailey Voltage Balance Electronic Telemeter Circuit

CONCENTRIC ORIFICES

Their Selection, Construction, and Use

By D. R. TAYLOR*

General Manager, Baton Rouge Water Works Co.
Baton Rouge, La.

THE concentric orifice is one of the simplest forms of differential producers; it is also inexpensive to make and install and suitable for many adaptations.

The purpose of this discussion is to give a simple explanation of the fundamentals of the concentric orifice as a flow measuring device, with typical examples, that may enable the average plant operator to attain a broader understanding and enjoy a wider use of the orifice, one or more of which is being used in the majority of water plants.

Nomenclature and Equations

As an aid to understanding the orifice method of measurement, it is necessary to have some knowledge of the equations and terms involved. These are shown herewith.

C = discharge coefficient
d_1 = diameter of pipe in inches
d_2 = diameter of orifice in inches
df = deflection of manometer liquid in inches
H = head in feet of water
h = head in inches of water
R = ratio of pipe diameter to orifice diameter
Rd = Reynolds number
Qd = gallons per day
Qm = gallons per minute
P.L. = permanent loss of head
S = specific gravity of manometer liquid

$$R = \frac{d_1}{d_2} \qquad \text{Eq. (1)}$$

$$d_2 = \frac{d_1}{R} \qquad \text{Eq. (2)}$$

$$Qd = \frac{28270\, C d_1^2 \sqrt{H}}{\sqrt{R^4 - 1}} \qquad \text{Eq. (3)}$$

$$Qm = \frac{1363.2\, C d_1^2 \sqrt{H}}{\sqrt{R^4 - 1}} \qquad \text{Eq. (4)}$$

$$Qm = \frac{5.667\, C d_1^2 \sqrt{h}}{\sqrt{R^4 - 1}} \qquad \text{Eq. (5)}$$

$$h = \left(\frac{Qm \sqrt{R^4 - 1}}{5.667\, C d_1^2} \right)^2 \qquad \text{Eq. (6)}$$

$$\sqrt{R^4 - 1} = \frac{5.667\, C d_1^2 \sqrt{h}}{Qm} \qquad \text{Eq. (7)}$$

$$*Rd = \frac{1353\, Qd}{d_1} \qquad \text{Eq. (8)}$$

$$*Rd = \frac{2812\, Qm}{d_1} \qquad \text{Eq. (9)}$$

*[Rd in equations 8 and 9 is the Reynold's Number for fresh water at 60° F., but is sufficiently accurate for ordinary use over the range of 40° to 80° F.]

Taps

The center of the upstream (high pressure) tap for the manometer, etc., should be located one pipe diameter from the upstream face of the orifice plate. The center of the downstream (low pressure) tap should be located one-half pipe diameter from the downstream face of the orifice plate.

The taps in a horizontal pipe run should be in the same plane relative to the axis of the pipe, and on the side of the pipe. The taps should never be made on the top of the pipe. In a vertical pipe run, they may be located at any position around the pipe, but always in the same vertical plane.

Fig. 1 shows the dimensions of the orifice plates for installation between standard pipe flanges. The plate should be made of monel metal, stainless steel, or bronze, in that order of preference. If the rim of the orifice (one-half of d_1-d_2) is greater than 1-in., an air vent hole of ⅛-in. diameter should be drilled through the top of the orifice plate as close to the top of the inside of the pipe as possible. This vent will prevent an accumulation of air on the upstream side of the orifice plate which would affect the accuracy of the orifice. The vent hole is, of course, not necessary when the installation is made in a vertical pipe. It is important that the upstream edge of the orifice be sharp, with no degree of roundness.

If it is necessary to use an orifice plate thicker than specified in Fig. 1, the downstream edge of the orifice should be bevelled at a 45° angle, until the thickness of the orifice meets the specifications shown. Table I shows the actual inside diameters of pipe and the value of the square of these diameters.

*In World War II served as Major, Corps of Engineers, A.U.S., Chief of Water and Sewage Section, 4th Service Command.

TABLE I

Actual Inside Pipe Diameters and the Square of the Diameter

Nominal Diameter (Inches)	WROUGHT IRON				CAST IRON			
	Standard		Extra Heavy		Pit Cast Class B		Centrifugal Class 150	
	d_1	d_1^2	d_1	d_1^2	d_1	d_1^2	d_1	d_1^2
2	2.067	4.272	1.939	3.760				
2½	2.469	6.096	2.323	5.396				
3	3.068	9.413	2.900	8.410				
4	4.026	16.209	3.826	14.638	4.10	16.810	4.12	16.974
6	6.065	36.784	5.761	33.189	6.14	37.700	6.16	37.946
8	7.981	63.696	7.625	58.140	8.03	64.481	8.21	67.404
10	10.020	100.400	9.750	95.063	9.96	99.202	10.16	103.226
12	12.000	144.000	11.750	138.060	11.96	143.040	12.20	148.840
14					13.98	195.440	14.55	211.700
16					16.00	256.000	16.60	275.560

In no case should the taps be less than ¼-in. (iron pipe thread). Suggested maximum tap sizes are ¼-in. for 2-in. pipe; ⅜-in. for 3-in.; ½-in. for 4 to 8-in. inclusive; ¾-in. for 10-in.; ¼-in. for 12-in.; ⅞-in. for 14-in.; and 1-in. for 16-in. pipe.

The nipples to be inserted in the tapped holes should have all burrs removed from their ends with a pipe reamer or file and they should be inserted no deeper than will cause their ends to be flush with the inside of the pipe. They should not protrude into the inside of the pipe.

Due to the thickness of the flanges, it is difficult to make the downstream tap at the proper location in the case of pipe with a diameter less than 2½ inches. Therefore, for pipe sizes smaller than 2½ inches, it is more satisfactory to purchase from the manufacturers orifice flanges already tapped and complete with the orifice plate.

Distortion of Flow In Bed

Sudden changes of direction of flow or slight changes in the symmetrical pattern of the water stream may cause marked inaccuracies in the results of flow measurements. For this reason, the orifice should be preceded and followed by minimum lengths of straight pipe. Such lengths are determined by the ratio (R) of pipe diameter to orifice diameter. The suggested minimum lengths expressed in diameters of pipe are shown in Table II.

TABLE II

Minimum Lengths of Straight Pipe for the Upstream and Downstream Sides of Orifices

(Expressed as the Number of Diameters of Pipe.)

Diameter Ratio (R)	Diameters of Pipe	
	Upstream	Downstream
1.25	20	5
1.50	12	4
2.00	7	4
2.50	6½	3½
3.00 and over	6	3

PIPE SIZE	O.D. STANDARD	O.D. (EXTRA HEAVY)	THICKNESS "T"
2"	4"	4 1/4"	3/32"
2 1/2	4 3/4	5	3/32
3	5 1/4	5 3/4	3/32
4	6 3/4	7	3/32
5	7 5/8	8 3/8	3/32
6	8 5/8	9 3/4	3/32
8	10 7/8	12	1/8
10	13 1/4	14 1/8	1/8
12	16	16 1/2	3/16
14	17 5/8	19	3/16
16	20 1/8	21 1/8	3/16
18	21 1/2	23 3/8	3/16
20	23 3/4	25 5/8	1/4
24	28 1/8	30 3/8	1/4

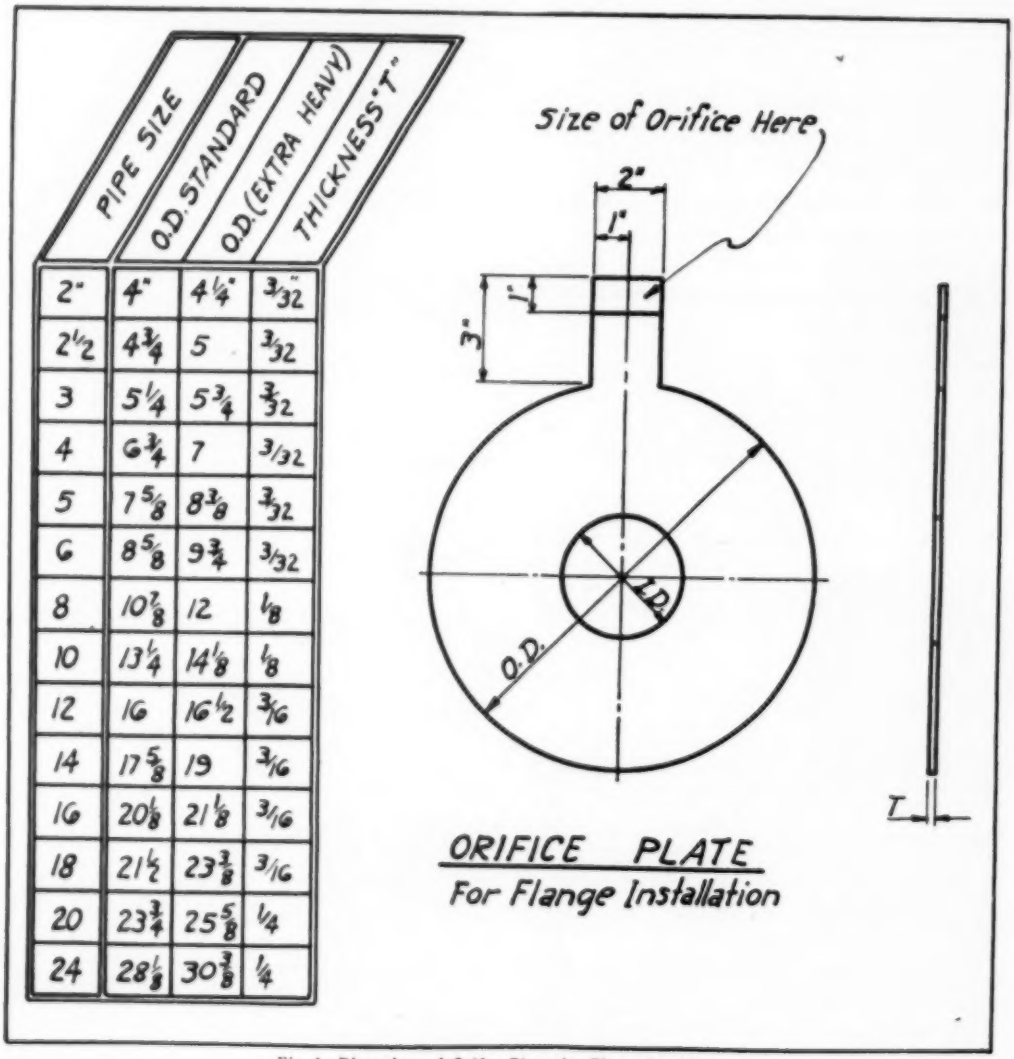


Fig. 1—Dimensions of Orifice Plates for Flange Installation

TABLE IV

Discharge Coefficients of Orifices

Reynolds Number →	R_d 15,000	R_d 30,000	R_d 75,000	R_d 100,000	R_d 150,000	R_d 200,000	R_d 500,000	R_d 1,000,000	R_d 1,500,000
Diameter of Pipe (Inches)	Coefficient where R=1.25								
2			.616	.614	.612	.610	.608	.606	
3			.618	.616	.613	.611	.608	.606	
4				.618	.614	.611	.608	.606	
6				.619	.615	.612	.608	.606	
8				.620	.616	.612	.608	.605	.605
10				.621	.616	.613	.608	.605	.604
12				.622	.617	.613	.608	.605	.604
	Coefficient where R=1.50								
2		.617	.615	.614	.613	.611	.610		
3		.618	.616	.614	.613	.611	.610	.609	
4				.614	.613	.611	.610	.608	
6				.615	.613	.611	.610	.608	
8				.615	.613	.612	.610	.608	.607
10				.615	.613	.612	.610	.609	.607
12				.616	.614	.612	.610	.609	.607
	Coefficient where R=2.00								
2	.612	.609	.608	.607	.606	.605	.604		
3, 4, 6, 8	.612	.609	.608	.607	.606	.605	.604	.603	
10 and 12		.609	.608	.607	.606	.605	.604	.603	.602
	Coefficient where R=2.50								
2 to 12	.608	.605	.603	.602	.601	.601	.600	.599	.598
	Coefficient where R=3.00								
2	.605	.602	.600	.600	.599	.598			
3 and 4	.604	.602	.600	.600	.599	.598	.597		
6 to 12	.604	.602	.600	.600	.599	.598	.597	.597	

It is, in fact, conducive to more positive accuracy if these lengths are exceeded, especially on the upstream side of the orifice, when this length of straight pipe is preceded by two elbows directly or closely connected. If the two elbows are positioned in different planes, the upstream lengths shown in Table II should be increased at least 50 per cent. If the required length cannot be obtained, straightening vanes should be installed 7½ pipe diameters preceding the orifice.

Reynold's Number

The Reynold's number (R_d) is a dimensionless ratio, dependent on a combination of diameter, velocity, density, and viscosity. By experiment it has been found that certain coefficients of discharge prevail for certain values of the Reynold's number. Reynold's number varies with temperature of the water, but for water with a temperature between 40° and 80° F., Equations (8) and (9) are sufficiently accurate for field use. Their use for all temperatures within these limits results in a maximum error of less than two tenths of one per cent and at 60° F. they are correct.

Table IV shows discharge coefficients of orifices for various diameter ratios, pipe diameters, and values of the Reynold's number.

Flow Meter Calibration
(Example 1)

It is desired to check the accuracy of an indicating and recording flow meter, which is actuated by an orifice and registers rate of flow in gallons per day, over a range from zero to four million. The pipe is 12-in. class 150 centrifugally cast, cast iron and the orifice diameter is 8 inches. The differential head, between the high and low pressure orifice taps is found to be 7.29 ft., when the meter is registering a rate of 3,000,000 gallons per day.

Given - $d_2 = 8$, $H = 7.29$, From table I, $d_1 = 12.20$, $d_1^2 = 148.84$,
Assume $C = 0.60$ Desired Q_d

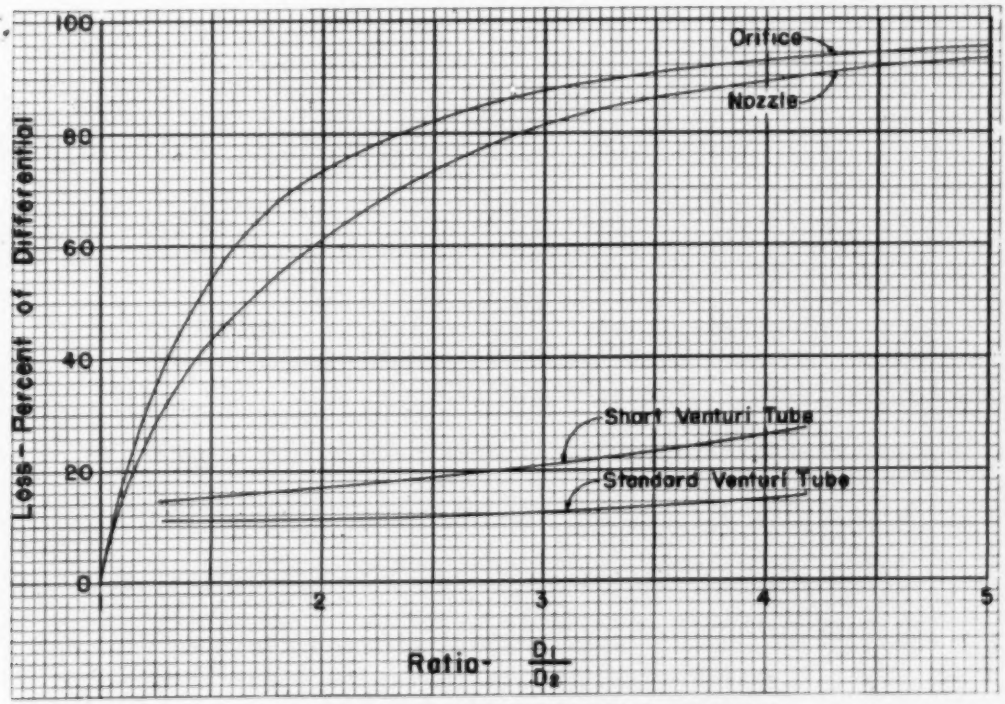


Fig. 2.—Permanent Loss of Head for Various Orifice Diameter Ratios (Expressed as Per Cent of Differential)

TABLE III

VALUES OF $\sqrt{R^2-1}$

R	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
1.250	1.201	1.204	1.207	1.210	1.213	1.217	1.220	1.223	1.226	1.229
1.260	1.233	1.236	1.239	1.242	1.246	1.249	1.252	1.255	1.259	1.262
1.270	1.265	1.268	1.272	1.275	1.278	1.281	1.284	1.288	1.291	1.294
1.280	1.297	1.300	1.304	1.307	1.310	1.314	1.317	1.320	1.323	1.326
1.290	1.330	1.333	1.337	1.340	1.343	1.346	1.349	1.353	1.356	1.359
1.300	1.362	1.366	1.369	1.372	1.375	1.379	1.382	1.385	1.388	1.391
1.310	1.395	1.398	1.401	1.405	1.408	1.411	1.414	1.418	1.421	1.424
1.320	1.427	1.430	1.433	1.437	1.440	1.443	1.446	1.449	1.453	1.456
1.330	1.459	1.462	1.466	1.469	1.472	1.475	1.478	1.482	1.485	1.488
1.340	1.491	1.495	1.498	1.501	1.504	1.508	1.511	1.514	1.517	1.520
1.350	1.524	1.527	1.530	1.533	1.537	1.540	1.543	1.546	1.549	1.553
1.360	1.556	1.559	1.562	1.566	1.569	1.572	1.575	1.579	1.582	1.585
1.370	1.588	1.592	1.595	1.598	1.601	1.605	1.608	1.611	1.614	1.617
1.380	1.621	1.624	1.627	1.630	1.634	1.637	1.640	1.643	1.647	1.650
1.390	1.653	1.656	1.660	1.663	1.666	1.669	1.673	1.676	1.679	1.682
1.400	1.686	1.689	1.692	1.695	1.699	1.702	1.705	1.709	1.712	1.715
1.410	1.718	1.722	1.725	1.728	1.731	1.735	1.738	1.741	1.744	1.748
1.420	1.751	1.754	1.757	1.761	1.764	1.767	1.771	1.774	1.777	1.780
1.430	1.784	1.787	1.790	1.794	1.797	1.800	1.803	1.807	1.810	1.813
1.440	1.817	1.820	1.823	1.826	1.830	1.833	1.836	1.840	1.843	1.846
1.450	1.849	1.853	1.856	1.859	1.863	1.866	1.869	1.873	1.876	1.879
1.460	1.882	1.886	1.889	1.892	1.896	1.899	1.902	1.906	1.909	1.912
1.470	1.916	1.919	1.922	1.926	1.929	1.932	1.936	1.939	1.942	1.945
1.480	1.949	1.952	1.955	1.959	1.962	1.965	1.969	1.972	1.975	1.979
1.490	1.982	1.985	1.989	1.992	1.996	1.999	2.002	2.006	2.009	2.012
1.500	2.016	2.019	2.022	2.026	2.029	2.032	2.036	2.039	2.042	2.046
1.510	2.049	2.052	2.056	2.059	2.063	2.066	2.069	2.073	2.076	2.079
1.520	2.083	2.086	2.090	2.093	2.096	2.100	2.103	2.106	2.110	2.113
1.530	2.117	2.120	2.123	2.127	2.130	2.134	2.137	2.140	2.144	2.147
1.540	2.150	2.154	2.157	2.161	2.164	2.167	2.171	2.174	2.178	2.181
1.550	2.184	2.188	2.191	2.195	2.198	2.202	2.205	2.208	2.212	2.215
1.560	2.219	2.222	2.226	2.229	2.232	2.236	2.239	2.243	2.246	2.250
1.570	2.253	2.256	2.260	2.263	2.267	2.270	2.274	2.277	2.280	2.284
1.580	2.287	2.291	2.294	2.298	2.301	2.305	2.308	2.312	2.315	2.318
1.590	2.322	2.325	2.329	2.332	2.336	2.339	2.343	2.346	2.350	2.353
1.600	2.357	2.360	2.364	2.367	2.371	2.374	2.378	2.381	2.384	2.388
1.610	2.391	2.395	2.398	2.402	2.405	2.409	2.412	2.416	2.419	2.423
1.620	2.426	2.430	2.433	2.437	2.440	2.444	2.447	2.451	2.455	2.458
1.630	2.462	2.465	2.469	2.472	2.476	2.479	2.483	2.486	2.490	2.493
1.640	2.497	2.500	2.504	2.507	2.511	2.515	2.518	2.522	2.525	2.529
1.650	2.532	2.536	2.539	2.543	2.546	2.550	2.554	2.557	2.561	2.564
1.660	2.568	2.571	2.575	2.578	2.582	2.586	2.589	2.593	2.596	2.600
1.670	2.603	2.607	2.611	2.614	2.618	2.621	2.625	2.629	2.632	2.636
1.680	2.639	2.643	2.647	2.650	2.654	2.657	2.661	2.665	2.668	2.672
1.690	2.675	2.679	2.683	2.686	2.690	2.693	2.697	2.701	2.704	2.708
1.700	2.711	2.715	2.719	2.722	2.726	2.730	2.733	2.737	2.741	2.744
1.710	2.748	2.751	2.755	2.758	2.762	2.766	2.770	2.773	2.777	2.781

R	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
1.720	2.784	2.788	2.792	2.795	2.799	2.803	2.806	2.810	2.814	2.817
1.730	2.821	2.825	2.828	2.832	2.836	2.839	2.843	2.847	2.850	2.854
1.740	2.858	2.861	2.865	2.869	2.872	2.876	2.880	2.884	2.887	2.891
1.750	2.895	2.898	2.902	2.906	2.909	2.913	2.917	2.921	2.924	2.928
1.760	2.932	2.935	2.939	2.943	2.947	2.950	2.954	2.958	2.962	2.965
1.770	2.969	2.973	2.977	2.980	2.984	2.988	2.991	2.995	2.999	3.003
1.780	3.006	3.010	3.014	3.018	3.022	3.025	3.029	3.033	3.037	3.040
1.790	3.044	3.048	3.052	3.055	3.059	3.063	3.067	3.070	3.074	3.078
1.800	3.082	3.086	3.089	3.093	3.097	3.101	3.105	3.108	3.112	3.116
1.810	3.120	3.124	3.127	3.131	3.135	3.139	3.143	3.146	3.150	3.154
1.820	3.158	3.162	3.166	3.169	3.173	3.177	3.181	3.185	3.188	3.192
1.830	3.196	3.200	3.204	3.208	3.211	3.215	3.219	3.223	3.227	3.231
1.840	3.235	3.238	3.242	3.246	3.250	3.254	3.258	3.262	3.265	3.269
1.850	3.273	3.277	3.281	3.285	3.289	3.293	3.296	3.300	3.304	3.308
1.860	3.312	3.316	3.320	3.324	3.328	3.331	3.335	3.339	3.343	3.347
1.870	3.351	3.355	3.359	3.363	3.367	3.370	3.374	3.378	3.382	3.386
1.880	3.390	3.394	3.398	3.402	3.406	3.410	3.414	3.417	3.421	3.425
1.890	3.429	3.433	3.437	3.441	3.445	3.449	3.453	3.457	3.461	3.465
1.900	3.469	3.473	3.477	3.481	3.485	3.489	3.493	3.496	3.500	3.504
1.910	3.508	3.512	3.516	3.520	3.524	3.528	3.532	3.536	3.540	3.544
1.920	3.548	3.552	3.556	3.560	3.564	3.568	3.572	3.576	3.580	3.584
1.930	3.588	3.592	3.596	3.600	3.604	3.608	3.612	3.616	3.620	3.624
1.940	3.628	3.632	3.636	3.640	3.644	3.648	3.653	3.657	3.661	3.665
1.950	3.669	3.673	3.677	3.681	3.685	3.689	3.693	3.697	3.701	3.705
1.960	3.709	3.713	3.717	3.721	3.725	3.730	3.734	3.738	3.742	3.746
1.970	3.750	3.754	3.758	3.762	3.766	3.770	3.774	3.778	3.783	3.787
1.980	3.791	3.795	3.799	3.803	3.807	3.811	3.815	3.819	3.824	3.828
1.990	3.832	3.836	3.840	3.844	3.848	3.852	3.857	3.861	3.865	3.869
2.000	3.873	3.877	3.881	3.885	3.890	3.894	3.898	3.902	3.906	3.910
2.010	3.914	3.919	3.923	3.927	3.931	3.935	3.939	3.943	3.948	3.952
2.020	3.956	3.960	3.964	3.968	3.973	3.977	3.981	3.985	3.989	3.994
2.030	3.998	4.002	4.006	4.010	4.015	4.019	4.023	4.027	4.031	4.035
2.040	4.040	4.044	4.048	4.052	4.057	4.061	4.065	4.069	4.073	4.078
2.050	4.082	4.086	4.090	4.094	4.099	4.103	4.107	4.111	4.116	4.120
2.060	4.124	4.128	4.133	4.137	4.141	4.145	4.150	4.154	4.158	4.162
2.070	4.167	4.171	4.175	4.179	4.184	4.188	4.192	4.196	4.201	4.205
2.080	4.209	4.214	4.218	4.222	4.226	4.231	4.235	4.239	4.244	4.248
2.090	4.252	4.256	4.261	4.265	4.269	4.274	4.278	4.282	4.287	4.291
2.100	4.295	4.299	4.304	4.308	4.312	4.317	4.321	4.325	4.330	4.334
2.110	4.338	4.343	4.347	4.351	4.356	4.360	4.364	4.369	4.373	4.377
2.120	4.382	4.386	4.391	4.395	4.399	4.404	4.408	4.412	4.417	4.421
2.130	4.425	4.430	4.434	4.438	4.443	4.447	4.452	4.456	4.460	4.465
2.140	4.469	4.473	4.478	4.482	4.487	4.491	4.495	4.500	4.504	4.509
2.150	4.513	4.517	4.522	4.526	4.531	4.535	4.540	4.544	4.548	4.553
2.160	4.557	4.562	4.566	4.570	4.575	4.579	4.584	4.588	4.593	4.597
2.170	4.602	4.606	4.610	4.615	5.619	4.624	4.628	4.633	4.637	4.642
2.180	4.646	4.651	4.655	4.659	4.664	4.668	4.673	4.677	4.682	4.686

TABLE III (Continued)

VALUES OF $\sqrt{R^2-1}$

R	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
2.190	4.691	4.695	4.700	4.704	4.709	4.713	4.718	4.722	4.727	4.731
2.200	4.736	4.740	4.745	4.759	4.754	4.758	4.763	4.767	4.772	4.776
2.210	4.781	4.785	5.790	4.794	4.799	4.803	4.808	4.812	4.817	4.821
2.220	4.826	4.830	4.835	4.840	4.844	4.849	4.853	4.858	4.862	4.867
2.230	4.871	4.876	4.880	4.885	4.890	4.894	4.899	4.903	4.908	4.912
2.240	4.917	4.922	4.926	4.931	4.935	4.940	4.944	4.949	4.954	4.958
2.250	4.963	4.967	4.972	4.977	4.981	4.986	4.990	4.995	5.000	5.004
2.260	5.009	5.013	5.018	5.023	5.027	5.032	5.036	5.041	5.046	5.050
2.270	5.055	5.060	5.064	5.069	5.073	5.078	5.083	5.087	5.092	5.097
2.280	5.101	5.106	5.111	5.115	5.120	5.125	5.129	5.134	5.139	5.143
2.290	5.148	5.153	5.157	5.162	5.167	5.171	5.176	5.181	5.185	5.190
2.300	5.195	5.199	5.204	5.209	5.213	5.218	5.223	5.227	5.232	5.237
2.310	5.242	5.246	5.251	5.256	5.260	5.265	5.270	5.275	5.279	5.284
2.320	5.289	5.293	5.298	5.303	5.308	5.312	5.317	5.322	5.327	5.331
2.330	5.336	5.341	5.346	5.350	5.355	5.360	5.365	5.369	5.374	5.379
2.340	5.384	5.388	5.393	5.398	5.403	5.407	5.412	5.417	5.422	5.426
2.350	5.431	5.436	5.441	5.446	5.450	5.455	5.460	5.465	5.470	5.474
2.360	5.479	5.484	5.489	5.494	5.498	5.503	5.508	5.513	5.518	5.522
2.370	5.527	5.532	5.537	5.542	5.546	5.551	5.556	5.561	5.566	5.571
2.380	5.575	5.580	5.585	5.590	5.595	5.600	5.605	5.609	5.614	5.619
2.390	5.624	5.629	5.634	5.639	5.643	5.648	5.653	5.658	5.663	5.668
2.400	5.673	5.677	5.682	5.687	5.692	5.697	5.702	5.707	5.712	5.717
2.410	5.721	5.726	5.731	5.736	5.741	5.746	5.751	5.756	5.761	5.765
2.420	5.770	5.775	5.780	5.785	5.790	5.795	5.800	5.805	5.810	5.815
2.430	5.820	5.825	5.829	5.834	5.839	5.844	5.849	5.854	5.859	5.864
2.440	5.869	5.874	5.879	5.884	5.889	5.894	5.899	5.904	5.909	5.914
2.450	5.919	5.924	5.929	5.934	5.939	4.944	5.949	5.953	5.958	5.963
2.460	5.968	5.973	5.978	5.983	5.988	5.993	5.998	6.003	6.008	6.013
2.470	6.018	6.023	6.028	6.033	6.038	6.043	6.048	6.053	6.058	6.063
2.480	6.069	6.074	6.079	6.084	6.089	6.094	6.099	6.104	6.109	6.114
2.490	6.119	6.124	6.129	6.134	6.139	6.144	6.149	6.154	6.159	6.164
2.500	6.169	6.175	6.180	6.185	6.190	6.195	6.200	6.205	6.210	6.215
2.510	6.220	6.225	6.230	6.236	6.241	6.246	6.251	6.256	6.261	6.266
2.520	6.271	6.276	6.281	6.287	6.292	6.297	6.302	6.307	6.312	6.317
2.530	6.322	6.327	6.333	6.338	6.343	6.348	6.353	6.358	6.363	6.369
2.540	6.374	6.379	6.384	6.389	6.394	6.399	6.405	6.410	6.415	6.420
2.550	6.425	6.430	6.436	6.441	6.446	6.451	6.456	6.461	6.467	6.472
2.560	6.477	6.482	6.487	6.492	6.498	6.503	6.508	6.513	6.518	6.524
2.570	6.529	6.534	6.539	6.544	6.550	6.555	6.560	6.565	6.570	6.576
2.580	6.581	6.586	6.591	6.597	6.602	6.607	6.612	6.617	6.623	6.628
2.590	6.633	6.638	6.644	6.649	6.654	6.659	6.665	6.670	6.675	6.680
2.600	6.686	6.691	6.696	6.701	6.707	6.712	6.717	6.722	6.728	6.733
2.610	6.738	6.744	6.749	6.754	6.759	6.765	6.770	6.775	6.781	6.786
2.620	6.791	6.796	6.802	6.807	6.812	6.818	6.823	6.828	6.834	6.839
2.630	6.844	6.850	6.855	6.860	6.866	6.871	6.876	6.882	6.887	6.892
2.640	6.897	6.903	6.908	6.914	6.919	6.924	6.930	6.935	6.940	6.946
2.650	6.951	6.956	6.962	6.967	6.972	6.978	6.983	6.988	6.994	6.999

R	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
2.660	7.005	7.010	7.015	7.021	7.026	7.032	7.037	7.042	7.048	7.053
2.670	7.058	7.064	7.069	7.075	7.080	7.085	7.091	7.096	7.102	7.107
2.680	7.113	7.118	7.123	7.129	7.134	7.140	7.145	7.150	7.156	7.161
2.690	7.167	7.172	7.178	7.183	7.188	7.194	7.199	7.205	7.210	7.216
2.700	7.221	7.227	7.232	7.237	7.243	7.248	7.254	7.259	7.265	7.270
2.710	7.276	7.281	7.287	7.292	7.298	7.303	7.309	7.314	7.320	7.325
2.720	7.331	7.336	7.342	7.347	7.353	7.358	7.364	7.369	7.375	7.380
2.730	7.386	7.391	7.397	7.402	7.408	7.413	7.419	7.424	7.430	7.435
2.740	7.441	7.446	7.452	7.457	7.463	7.468	7.474	7.480	7.485	7.491
2.750	7.496	7.502	7.507	7.513	7.518	7.524	7.529	7.535	7.541	7.546
2.760	7.552	7.557	7.563	7.568	7.574	7.580	7.585	7.591	7.596	7.602
2.770	7.607	7.613	7.619	7.624	7.630	7.635	7.641	7.647	7.652	7.658
2.780	7.663	7.669	7.675	7.680	7.686	7.692	7.697	7.703	7.708	7.714
2.790	7.720	7.725	7.731	7.737	7.742	7.748	7.753	7.759	7.765	7.770
2.800	7.776	7.782	7.787	7.793	7.799	7.804	7.810	7.816	7.821	7.827
2.810	7.833	7.838	7.844	7.850	7.855	7.861	7.867	7.872	7.878	7.884
2.820	7.889	7.895	7.901	7.906	7.912	7.918	7.923	7.929	7.935	7.941
2.830	7.946	7.952	7.958	7.963	7.969	7.975	7.981	7.986	7.992	7.998
2.840	8.003	8.009	8.015	8.021	8.026	8.032	8.038	8.044	8.049	8.055
2.850	8.061	8.066	8.072	8.078	8.084	8.090	8.095	8.101	8.107	8.113
2.860	8.118	8.124	8.130	8.136	8.141	8.147	8.153	8.159	8.164	8.170
2.870	8.176	8.182	8.188	8.193	8.199	8.205	8.211	8.217	8.222	8.228
2.880	8.234	8.240	8.246	8.251	8.257	8.263	8.269	8.275	8.280	8.286
2.890	8.292	8.298	8.304	8.310	8.315	8.321	8.327	8.333	8.339	8.345
2.900	8.350	8.356	8.362	8.368	8.374	8.380	8.385	8.391	8.397	8.403
2.910	8.409	8.415	8.421	8.426	8.432	8.438	8.444	8.450	8.456	8.462
2.920	8.468	8.473	8.479	8.485	8.491	8.497	8.503	8.509	8.515	8.521
2.930	8.526	8.532	8.538	8.544	8.550	8.556	8.562	8.568	8.574	8.580
2.940	8.586	8.591	8.597	8.603	8.609	8.615	8.621	8.627	8.633	8.639
2.950	8.645	8.651	8.657	8.663	8.669	8.675	8.681	8.687	8.692	8.698
2.960	8.704	8.710	8.716	8.722	8.728	8.734	8.740	8.746	8.752	8.758
2.970	8.764	8.770	8.776	8.782	8.788	8.794	8.800	8.806	8.812	8.818
2.980	8.824	8.830	8.836	8.842	8.848	8.854	8.860	8.866	8.872	8.878
2.990	8.884	8.890	8.896	8.902	8.908	8.914	8.920	8.926	8.932	8.938
3.000	8.944	8.950	8.956	8.962	8.968	8.975	8.981	8.987	8.993	8.999
3.010	9.005	9.011	9.017	9.023	9.029	9.035	9.041	9.047	9.053	9.059
3.020	9.065	9.071	9.078	9.084	9.090	9.096	9.102	9.108	9.114	9.120
3.030	9.126	9.133	9.138	9.145	9.151	9.157	9.163	9.169	9.175	9.181
3.040	9.187	9.193	9.200	9.206	9.212	9.218	9.224	9.230	9.236	9.243
3.050	9.249	9.255	9.261	9.267	9.273	9.279	9.285	9.292	9.298	9.304
3.060	9.310	9.316	9.322	9.329	9.335	9.341	9.347	9.353	9.359	9.366
3.070	9.372	9.378	9.384	9.390	9.396	9.403	9.409	9.415	9.421	9.427
3.080	9.434	9.440	9.446	9.452	9.458	9.465	9.471	9.477	9.483	9.489
3.090	9.496	9.502	9.508	9.514	9.520	9.527	9.533	9.539	9.545	9.552
3.100	9.558	9.564	9.570	9.577	9.583	9.589	9.595	9.602	9.608	9.614

By Eq. (1), $R = \frac{12.20}{8} = 1.525$

From Table III, $\sqrt{R^4-1} = 2.1$

By Eq. (3), $Q_d = \frac{28270 \times 0.60 \times 148.84 \times 2.7}{2.1} = 3,245,900$

By Eq. (8), $R_d = \frac{1.253 \times 3,245,900}{8} = 792,400$

From Table III, by interpolating it is found that for 12" pipe centrifugally cast when $R = 1.50$ and $R_d = 792,400$, that the C value is 0.6094 instead of 0.60 (assumed), therefore,

$Q_d = 3,245,900 \times \frac{0.60942}{0.60} = 3,296,861$

Inasmuch as the meter was registering only 3,000,000, it was under-registering an amount calculated as follows:

$$\text{Error} = \frac{3,296,861 - 3,000,000}{3,296,861} = 9.0 \text{ per cent.}$$

In other words the meter was registering 9 per cent low at the 3 mgd. rate. Now, the rate of flow should be varied and similar tests made at other rates of flow, over the entire range of the instrument, for accurate calibration. For rates of flow in gallons per minute, Eq. (4) and Eq. (5) may be used.

Selecting the Size of Orifice
(Example 2)

Three pumps with capacities of 50, 100, and 150 gallons per minute are controlled by pressure switches and operate separately or simultaneously, depending on the demand. It is desired to install an orifice to operate a proportional chemical feeder, which is differentially actuated. The feeder will not operate with a differential of less than four inches of water. On the other hand, it is not desired to create any more artificial head than is necessary, on the pumps. The discharge pipe from the station is 6-in. class 150, centrifugal cast iron.

Given - Minimum $Q_m = 50$

Maximum $Q_m = 50 + 100 + 150 = 300$

Minimum $h = 4$ Assume $C = 0.61$

From Table I, $d_1 = 6.16$ and $d_1^4 = 37.946$

Desired - Orifice diameter d_2 to obtain an h of 4 inches at minimum Q_m and lowest possible h at maximum Q_m

By Eq. (7), $\sqrt{R^4-1} = \frac{5.667 \times 0.61 \times 37.946 \times 2}{50} = 5.25$

From Table III, it will be seen that for $\sqrt{R^4-1} = 5.25$ that $R = 2.312$

By Eq. (2), $d_2 = \frac{6.16}{2.312} = 2.66$ in.

The loss of head for the maximum Q_m should next be determined.

By Eq. (6), $h = \left(\frac{300 \times 5.25}{5.667 \times .61 \times 37.946}\right)^2 = 144$ in.

This represents a momentary loss of head, but all differential producers recover part of the temporary loss of head, which they produce.

Fig. 2 shows the permanent loss of head through various differential producers, expressed in per cent of differential. Such head loss is dependent on the diameter ratio (R) and it will be seen from Fig. 2 that the permanent loss for R = 2.312 is only 79 per cent of the momentary orifice differential. Therefore, in this case the permanent loss of head at 300 gpm. is

$$\text{P.L.} = 0.79 \times 144 = 113.76 \text{ in.}$$

For some problems of this nature, that of determining the size of the orifice, to obtain some desired differential, it is sufficiently accurate to use a coefficient of 0.61 and it is not necessary to determine Q_m and R_d and recalculate with the resulting exact coefficient, because the average error effected by not so doing will be less than three tenths of one per cent.

It is customary practice not to impose more than 100 inches of differential head loss on pumps at maximum pumping capacity, if such can be avoided. It is often found, however, that the pump in question is operating at a total dynamic head of several feet below that for which it was designed and is delivering more than its designed capacity. In such a case the imposition of some artificial head may do no harm and may even be beneficial, and actually conducive to pumping economy.

If this is not found to be the case, and the calculated permanent loss of head (P.L.) through the proposed orifice at the maximum rate is found to be too great, after considering all pertinent circumstances, then a Venturi tube or a velocity type meter, whose permanent head loss is low (see Fig. 2) or some other type of metering equipment should be used.

Comparing the Venturi Tube and the Orifice Meter

All formulas given are equally applicable to the Venturi tube and the flow nozzle. The only difference is in the value of the coefficient (C) and the permanent loss of head. An average coefficient of 0.977 may be assumed for the standard Herschel (long) Venturi tube; however, for extremely accurate calibration the value of C. for the tube in question should be secured from the manufacturer.

With the same conditions as shown in Example 2, the results with a Venturi tube instead of an orifice would be as follows, assuming C equal to 0.977.

By Eq. (7), $\sqrt{R^4-1} = \frac{5.667 \times .977 \times 37.946 \times 2}{50} = 8.4$

From Table III, $R = 2.5085$

By Eq. (2), $d_2 = \frac{6.16}{2.5085} = 2.118$ in.

For $Q_m = 300$, by Eq. (6);

$h = \left(\frac{300 \times 8.4}{5.667 \times .977 \times 37.946}\right)^2 = 144$ in.

From Fig. 2, P.L. = 0.20 x 144 = 28.8 in., which would be a very acceptable permanent loss.

If the purpose of the installation is for chemical feeding only and does not include the possibilities of flow measurement, it may be more economical to use a variable differential orifice, which is designed on the principle of a horizontal swing check valve and produces proportionate differential, but the curve is flatter than that of the fixed orifice. Information concerning this type of orifice may be secured from the McKays Co. of Saint Paul, Minn.

Standard orifice plates may be purchased with any size orifice, from any of the flow measuring equipment manufacturers. if it is preferred not to make them.

Chlorine Control and Meter Combination
(Example 3)

A source of water supply consists of six wells with capacities of 100 gpm. each, all discharging through an 8-in. common discharge of class 150 centrifugal cast iron pipe. As a contrast to the problem in Example 2, these wells are operated in groups of either three or six simultaneously. It is desired to install an automatic chlorinator and a flow meter, both to be actuated by the same orifice. It will be necessary to install a separate pair of taps (on opposite sides of the pipe) for each piece of equipment. The flow meter requires a differential of 12 inches at 300 gpm.

Given - Minimum $Q_m = 300$ at $h = 12$ in.

Maximum $Q_m = 600$

From Table I, $d_1 = 8.21$, and $d_1^4 = 67.404$;

Assume $C = 0.61$

Desired - d_2 and h when $Q_m = 600$

By Eq. (7), $\sqrt{R^4-1} = \frac{5.667 \times 0.61 \times 67.404 \times 3.464}{300} = 2.690$

From Table III, $R = 1.694$ and by Eq. (2) $d_2 = \frac{8.21}{1.694} = 4.847$ in.

For maximum flow, $Q_m = 600$

By Eq. (6), $h = \left(\frac{600 \times 2.69}{5.667 \times 0.61 \times 67.404}\right)^2 = 48$ in.

From Fig. 2, P.L. = 0.64 x 48 = 30.7 in.

Testing Pumps
(Example 4)

A pump station consists of three pumps with rated capacities of 350, 700, and 750 gpm. The common discharge is 10-in. class 150 centrifugal cast iron pipe. A 13¼-in. x 6.655-in. orifice plate (see Fig. 1) has been installed to operate an automatic chlorinator. There is no measuring equipment. It is desired to determine the output of the pumps under actual operating conditions. The 700 gpm. pump will be tested first.

Given - $d_2 = 6.655$; From Table I, $d_1 = 10.16$ and $d_1^2 = 103.226$

With a manometer h_1 is found to be 18".

Assume $C = 0.61$ Desired - Q_m

By Eq. (1) $R = \frac{10.16}{6.655} = 1.527$

From Table III, $\sqrt{R^4 - 1} = 2.106$

By Eq. (5) $Q_m = \frac{5.667 \times 0.61 \times 103.226 \times 4.243}{2.106} = 719$

By Eq. (3), $R_d = \frac{1812 \times 719}{6.655} = 303,800$

From Table III, for $R = 1.50$, and $R_d = 303,800$ for 10 in. pipe it is found that $C = 0.6116$

This value is so close to the value of $C = 0.61$ which was used, that no correction is necessary and it may be considered that the discharge of the pump is 719 gpm.

The other two pumps may be tested in a similar manner, separately or while operating simultaneously or in any number of combinations. With the use of a pressure gage and a vacuum gage (or other manometer), the total dynamic head under which the pumps are operating could easily be determined and that information, together with the output, would enable the operator to ascertain from the manufacturer's head-capacity characteristics curve, whether or not the pumps meet the specifications under which they were purchased.

Accuracies

Ratios (R) of less than 1.40 should be avoided whenever possible and ratios of less than 1.25 should never be used, for accurate flow measurement. An accuracy of plus or minus one per cent may be expected with ratios of 1.40 or greater and of plus or minus two per cent with ratios from 1.25 to 1.40. With ratios under 1.25, there are so many unreliable conditions, that if such ratios are unavoidable, the orifice should be calibrated "in place" over its entire range.

With respect to accuracy, one other warning should be given. When using or checking old flow measuring equipment, where scale, tuberculation, or wear is known or suspected, actual measurements should be made of d_1 and d_2. In the case of an orifice, if the upstream edge of the orifice becomes rounded, it should be replaced. A keen sharp edge is the first requirement of an orifice for accurate flow measurement.

The Relation of Flow and Head Differential
(Examples 5 and 6)

Differential head varies directly with the square of the flow.

that is, $h_2 = h_1 \left(\frac{Q_2}{Q_1}\right)^2$ ——— Eq. (10)

After the differential head has been determined for one rate of flow, the differential head for any other rate of flow may be easily determined by the above simple formula.

With a flow of 500 gpm. if the differential head is found to be 12 inches, what will the differential head be for a flow of 1000 gpm.?

Given - $Q_1 = 500$, $h_1 = 12$ in. $Q_2 = 1000$, Desired - h_2

By Eq. (10); $h_2 = 12\left(\frac{1000}{500}\right)^2 = 48$ in.

After the rate of flow has been determined for one differential head, the rate of flow for any other differential head may also be easily determined by the following simple formula. Since the rate of flow varies directly with the square root of the differential head, the equation for this calculation is

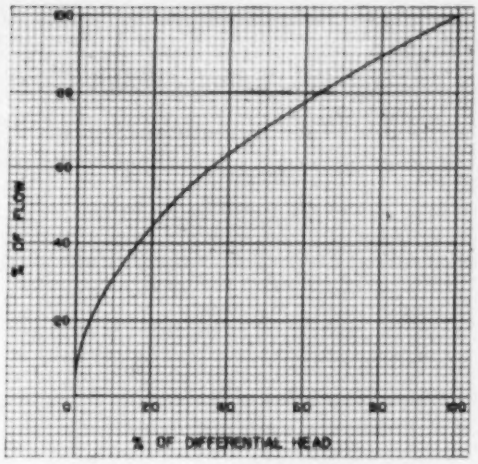


Fig. 3—Relation of Flow and Differential Head

$$Q_2 = Q_1\sqrt{\frac{h_2}{h_1}} \quad \text{——— Eq. (11)}$$

If, with a differential head of 90 inches the rate of flow is found to be 1200 gpm., what will be the rate of flow with a differential head of 45 inches? (See Fig. 3)

Given, $h_1 = 90$ in., $Q_1 = 1200$, $h_2 = 45$ in. Desired - Q_2

By Eq. (11), $Q_2 = 1200\sqrt{\frac{45}{90}} = 848$ gpm.

The Manometer

The simplest method of determining the differential head produced by any differential producer is with the use of a U tube or manometer. Care should be exercised to be certain that all air has been expelled from the manometer before any measurements are made of the deflection of liquid level in the tubes.

The following equations apply to the manometer and its readings. The symbols involved are

H = Head of water in feet
h = Head of water in inches
d_f = Deflection of manometer liquid in inches
S = Specific gravity of manometer liquid.

$h = d_f(s-1)$ ——— Eq. (12)

$H = \frac{h}{12}$ ——— Eq. (13)

$d_f = \frac{h}{(s-1)}$ ——— Eq. (14)

$s = \frac{h}{d_f} + 1$ ——— Eq. (15)

In addition to mercury, there are various liquids that may be used in manometer, all of which should be colored with an oil soluble dye, so that the point of division between the liquid being used and the water may be readily visible. Following are some of the liquids more commonly used.

Material	Gravity*
Carbon Tetrachloride	1.60
Acetylene Tetrabromide	2.95
Mercury	13.58

*Approximate Specific Gravity

When low rates of flow are encountered, requiring a liquid with a low specific gravity, so as to secure the maximum differential reading in the manometer tubes, carbon tetrachloride may be diluted with benzine to obtain any specific gravity from 1.60 down to 1.10. The specific gravity of the liquid being used

may be determined with a hydrometer, but such determination should always be made immediately *after* the liquid has been used. That value should be used in all calculations, because the specific gravity of the oils varies materially with temperature. The gravity of mercury need not be checked after taking differential readings and the gravity of 13.58 may be taken as a constant.

If possible, a liquid with a specific gravity that will produce a deflection of 12 inches or more should be used, because it is easily understood that an error of 1/16-in. in the measurement of a deflection, will result in a very much smaller error when the deflection is large than when it is relatively small.

Determining the Most Desirable Gravity for Manometer Liquids

If the approximate rate of flow is known, the approximate specific gravity required for any desired deflection may be determined as the following example indicates.

A 500 gpm. pump is to be tested.

Given - $d_1 = 8.21$, $d_1^2 = 67.404$, $d_2 = 5$ in., Assume $C = 0.61$

Desired - The specific gravity of manometer liquid that will produce a deflection of approx. 16 in.

First it is necessary to determine the approx. h.

By Eq (1), $R = \frac{8.21}{5} = 1.64$

From table III, $\sqrt{R^4 - 1} = 2.497$

By Eq (6), $h = \left(\frac{500 \times 2.497}{5.667 \times 0.61 \times 67.404}\right)^2 = 28.7$ in.

By Eq (15), $S = \frac{28.7}{16} + 1 = 2.79$

Since acetylene tetrabromide has a gravity (S) of 2.95 it it may be used straight and it will give a deflection of approx. 14.8 in. calculated as follows:

By Eq (14), $d_2 = \frac{28.7}{(2.95 - 1)} = 14.8$ in.

In case of high rates of flow which, upon pre-calculation as above, may cause the deflection of acetylene tetrabromide to exceed the capacity of the manometer, mercury should be used. For lower rates of flow, carbon tetrachloride diluted with benzine should be employed. With such a mixture of specific gravity 1.25, a deflection of 24 in. is secured from a differential through the orifice of only 6 inches of water head in accordance with Eq. (12)

$$h = 24(1.25 - 1.00) = 6 \text{ in.}$$

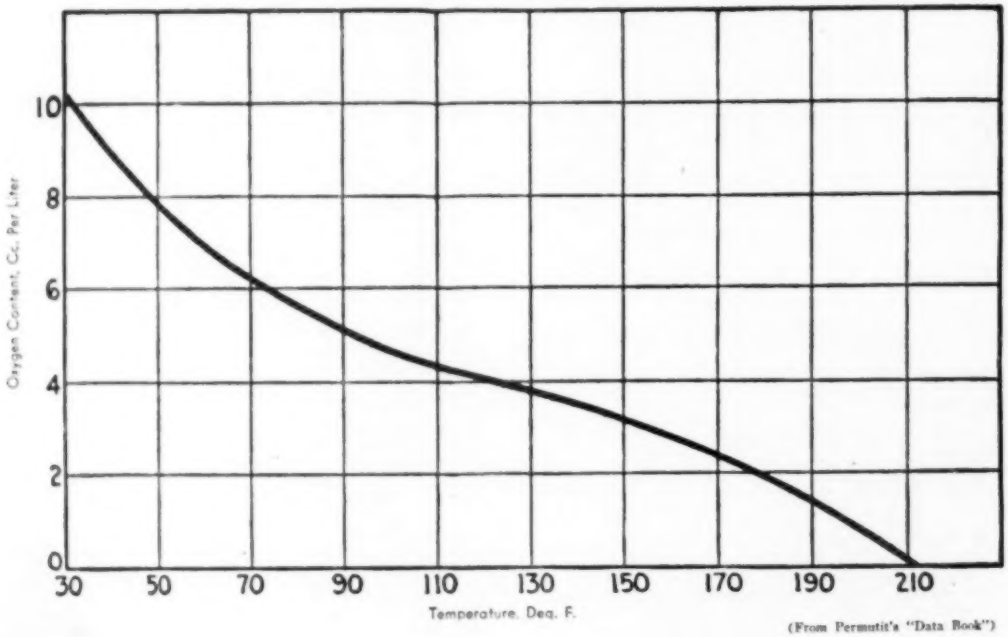
For the purpose of manufacturing design, academic research, or for the measurement of the flow of hot water or liquids with specific gravities and viscosities different from those of water, it is suggested that reference be made to "Fluid Meters, Their Theory and Application", (4th Edition) published by the American Society of Mechanical Engineers, and considered the outstanding compendium on the design and use of flow measuring equipment.

References

Fluid Meters, Theory and Application—A.S.M.E.
Handbook of Hydraulics—King—McGraw-Hill Book Co.
Cameron Hydraulic Data—Ingersoll-Rand Co.
Flow of Fluids—Crane Co.
Bulletin No. 22—Simplex Valve and Meter Co.
Bulletin No. 236—Builders Iron Foundry Co.
Instructions—Republic Flow Meter Co.
Instructions—The Brown Instrument Co.
Bulletin No. 301-A—The Bailey Meter Co.

SOLUBILITY OF OXYGEN IN PURE WATER

At Various Temperatures



(From Permutit's "Data Book")

WATER USED BY GROWING TREES*

Observations Verify Graph

ADOLPH F. MEYER

Cons. Hyd. Engr., Minneapolis, Minn.

AMONG the basic tools of engineering are empirical graphs and formulas. The practicing engineer must continually check the results secured through the use of these tools, not only to retain his confidence in them, but also to make needed modifications as new information comes to light.

It is often desirable to know the depth of water used by growing trees, in addition to the evaporation loss from the leaves of the trees and from the bare soil or cover crops surrounding the trees. These evaporation losses are in addition to the water used by the trees, and the two together constitute evapo-transpiration, or consumptive use. A useful tool for determining transpiration is the Meyer Base Curve which I developed over 25 years ago and first published in the ASCE TRANSACTIONS for 1915 (Vol. 79, p. 1094).

A measure of the accuracy of this curve may be obtained by comparing transpiration values derived from it with the results of actual observations recorded in Bulletin No. 686 of the University of California Agricultural Experiment Station at Berkeley, published in March 1944. The ground in an orchard of citrus fruit trees was mulched to prevent evaporation, and irrigation water was applied through furrows. The transpiration loss was determined by frequent soil sampling for moisture. In Table I, I have tabulated only the average observed values and have added the values computed from the base curve for comparison.

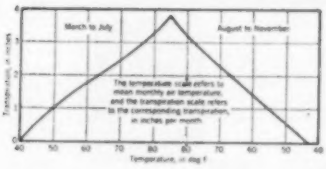

March to July
August to November
The temperature scale refers to mean monthly air temperature, and the transpiration scale refers to the corresponding transpiration, in inches per month.
Transpiration, in inches
Temperature, in deg F

Fig. 1. Base Curve of Transpiration is empirical graph which constitutes one of tools of engineering. Curve is reproduced from "Computing Runoff from Rainfall and other Physical Data," ASCE Transactions, Vol. 79 (1915), p. 1094.

*From "Civil Engineering," June 1951.

TABLE I. OBSERVED TRANSPIRATION IN INCHES OF DEPTH OVER TWO ORCHARD AREAS

Compared with values obtained from Meyer's Base Curve of Transpiration, Fig. 1.

Test Locations and Months	Observed Transpiration, In.			Transpiration from Base Curve, In.	Mean Temperature*
Coastal Zone, Orange County:	Older vigorous trees	Younger trees	Average		
April	1.3	1.3	1.3	1.6	59.2
May	1.9	1.5	1.7	1.9	62.7
June	2.7	1.7	2.2	2.2	67.0
July	3.1	1.9	2.5	2.5	71.0
August	2.9	1.9	2.4	2.4	71.2
September	2.4	1.7	2.05	2.1	68.6
October	1.7	1.3	1.5	1.7	63.5
Totals	16.0	11.3	13.65	14.4	

Interior Zone, Riverside and San Bernardino Counties:	Observed Transpiration, In.		Transpiration from Base Curve, In.	Mean Temperature†
	Excellent and good trees	Fair trees		
April	2.0	1.4	1.7	60.0
May	2.6	2.1	2.0	64.1
June	3.0	2.6	2.4	70.2
July	2.8	3.2	2.9	76.0
August	3.6	3.2	2.8	75.9
September	3.0	2.4	2.2	70.7
October	2.6	1.8	1.8	64.7
Totals	20.6	16.6	15.8	

* At Santa Anna, in degrees Fahrenheit. † At San Bernardino and Riverside, in degrees Fahrenheit.

Evidently the transpiration values had from the base curve, even without the application of any coefficient, are close enough for practical use on trees of medium size, in fair condition. Available moisture, as well as type and density of vegetal cover, must of course be considered in all estimates of transpiration loss. Such factors as these can be expressed as a coefficient to be applied to the base-curve values.

Dry Feed Dosages in Grains Per Gallon Converted to Ounces Per Minute

Grains Per Gallon	Weight in Ounces Per Minute — Rate in Gallons Per Minute									
	50	100	150	200	250	300	350	400	450	500
0.1	0.0114	0.0228	0.0342	0.0457	0.0571	0.0685	0.0799	0.0914	0.1028	0.1142
0.5	0.0571	0.1143	0.1714	0.2285	0.2857	0.3428	0.3999	0.4561	0.5142	5.7140
1.0	0.1142	0 2285	0 3428	0.4571	0.5714	0.6856	0.7999	0.9142	1.0285	1.1428
2.0	0.2285	0.4571	0.6856	0.9142	1.1428	1.3713	1.5999	1.8284	2.0570	2.2856
3.0	0.3428	0 6856	1.0285	1.3713	1.7142	2.0570	2.3998	2.7427	3.0855	3.4284
4.0	0.4571	0.9142	1.3713	1.8284	2.2856	2.7427	3.1990	3.6570	4.1141	4.5712
5.0	0.5714	1.1428	1.7142	2 2856	2.8570	3.4284	3.3997	4.5712	5.1426	5.7140

$$\text{Ounces per minute} = \frac{\text{Dosage in g. p. g. x Rate in g. p. m.}}{437.5}$$

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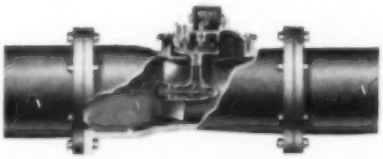

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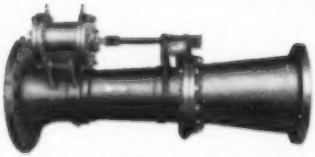

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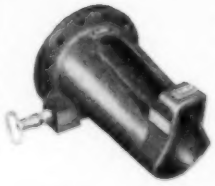

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SELECTING THE RIGHT METER

By ROGER W. ESTY

Superintendent, Water Works and Sewerage, Danvers, Mass.

IN days gone by, the thought of "What shall we set for a meter on a service line?" was not given the consideration warranted. The expense involved apparently did not appear to be a factor, because the size of the pipe installed was generally used as the determining factor in selecting the size of meter for the installation.

Since those days meters have reached a much higher degree of perfection and now, at reasonable cost, meters can be purchased to fit any service required; and, can be depended upon to give satisfactory results.

Especial care should be exercised when purchasing a meter because this device serves as the cash-register of the system. When purchasing a meter do not let the price be the determining factor; for, as you know, the older we get the more and more do we realize that you get just about what you pay for. There is no such thing, nowadays, as truth in a claim that "It is just as good for one-half the price."

We must not forget the obligation we owe to those we serve. We must not spend their money recklessly or unwisely.

Several years ago, at Danvers, we had a water waste survey made to check up on our consumption, which apparently was gradually creeping upward without any particular reason. Much to our surprise, we found no unreasonable leakage, but found that all of our large meters were under-registering, some as much as 50 or 60 per cent. On large meters this constitutes a sizable and serious loss.

In the past, we never tested these meters. And, as long as they kept running and the monthly readings were comparative little, if any, attention was given them. When we found a stopped one we would take it apart and clean it and make whatever repairs found necessary. We didn't know whether the meter recorded accurately or not. We merely assumed that if it was properly cleaned and repaired it must be right.

After our water waste survey we changed practically every meter. Some we had rebuilt. As time went on we found that this change had been very unsatisfactory. We were suspicious of the accuracy of the readings of one large meter, realizing that its registrations must be too low. To obtain a test on it, we put in two one-inch corporation checks, brought them together, and then from this junction extended a fire hose to a two-inch test disc-meter which had been previously checked for accuracy. From this set-up approximately 200 gpm. was obtainable. Apparently our suspicions had been right because we found the meter under-registering. As a result of that test, we started tapping in just beyond all of the other large meters for additional testing.

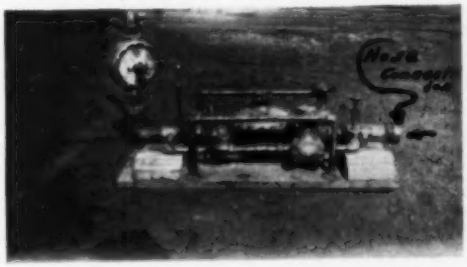
Meter By-Pass Lines Proved Their Worth

From the results of this work, we decided to take out all of our institution and industrial meters, replacing them with new meters. In each case we provided a by-pass line, a test tee and the necessary gates, so that tests and repairs could be made at any time without inconvenience to the customer.

In my opinion the money spent constituted the best investment we have ever made for convenient and money saving maintenance. It is a highly justifiable expense and no meter of any consequence should be set without being provided with a properly gated by-pass with a test plug inserted.

We made mistakes in our first set-up that I would correct if I had to do the work over again. In making changes my first correction would be to set the meter on the by-pass, line and leave the main line unobstructed, to take care of large emergency demands such as would be needed at a fire. As a general rule, a meter much smaller than the size of the supply pipe can be, and should be used and there is also a saving to be had in the cost of the smaller fittings required. This is now the practice followed in Danvers.

Then, next, all gates should be provided with rising stem valves. There is a possibility of leaving gates opened or closed where the standard (non-indicating) gate stem is used. Visualization is a great safeguard and protection and at a glance one can tell the position of a rising stem valve.



Portable Meter Testing and Flow Measuring Outfit

Oversize Meters—Why?

After this new set-up of meters had been in for a few years, we made a 3 or 4 day test on each meter, running the recording testing device twenty-four hours each day. The results were surprising—even astounding. Meter line requirements on 6 and 8-inch pipe lines, provided with meters of the same size as the pipe, showed that at no time did the demand exceed on the 6-inch meter 25 gpm. and on the 8-inch meter 75 gpm.

From these results it was apparent that: In the first case a ¼-inch meter would amply take care of the normal demands on the 6-inch service; and in the second instance a 1¼-inch meter would suffice on the 8-inch service. But these meters were on lines supplying hydrants, and therefore the smaller meters could not be used. It is my opinion, however, that a 4-inch meter—if not a 3-inch meter—will prove ample. A 3-inch meter on a by-pass will supply two powerful fire streams and in most cases this will be sufficient. If a greater demand should be required the main line can be opened. Since we have a man who answers every fire alarm, he has been instructed in every instance to open up the gate on the unmetered side, regardless of how small the fire might be.

What Size Service Line

When laying a service main I thoroughly believe in laying one that will more than take care of the service demanded. Larger lines reduce friction and deliver volume up to the point of the demand. The owner should be interviewed regarding what he feels will be his maximum demand in gallons per minute. On commercial lines, I try to have the customer visualize a barrel and then tell him that that barrel holds 50 gallons. Then I ask, how much more or less than 50 gallons per minute will he use? He can readily make a comparison in his mind between the 50 gallons and the amount he is going to use and he can then easily judge about how much he will use, and it is seldom you will find any user using more than "a barrel a minute." Cubic feet means nothing to the customer, and even gallons per minute means little, but the barrel method of determining the amount of water he might use, is much easier for him to understand and has not failed yet in giving to me the information that I have wanted in determining the size of meter and service needed.

The type of service and demand should be instrumental in determining the type of meter that should be used. Consideration of the small flows should be given prior consideration because 90 per cent of the flows come under the range of the smallest capacities of the large meters. If a large continuous flow is used, then naturally a meter to register large flows should be used as there are no small streams to be considered.

I have a case in my own system, at Danvers, where all of the water is repumped and this pump operates at about 500 gpm. until the tank is full, then it automatically shuts off and no more water passes through the meter until the level of the tank drops sufficient to kick in the automatic pump switch. In this case a meter to pick up minor flows, leakage, etc., is not needed, because the rate of flow is 500 gpm. or nothing.

The selection of the meter, should in my opinion, be left with the water works officials and *not* to the customer. The ownership of the meter should also be retained by the water department and *not* by the customer. By experience, water works managers are much better qualified than anyone else to select the proper meter which, in justice to all, must be the most adaptable to the desired type of service it is selected for.

WATER METER TESTING*

Principles and Practice

The testing of a water meter is very simple. It consists of checking the registration of the meter against the actual volume of water passing through the meter, as measured in an accurate volumetric tank or weighed on accurate scales.

Meter accuracy may be defined as the quotient obtained by dividing the meter reading by the actual volume of water. Thus a meter registering 9 gallons when 10 gallons are run through it has an accuracy of 9/10 or 90%. A meter registering 52 cubic feet on an actual volume of 50 cubic feet is 52/50, or 104% accurate.

Meter accuracy is commonly expressed in percentage fast or slow. Thus a meter which records 95 gallons when 100 gallons are run through it under-registers or is slow by 5%. A meter registering 102 gallons on the same volume would be 2% fast.

Good Practice in Testing

Before starting a test, water should be run through the meter or meters at a high rate, say 10 or 15 gallons per minute, until all the air is out of the meters and the line, and the delivery pipe to the tank is as full or as empty as it will be at the end of the test. Start the test flow with the test hand of the meter or meters on an even starting position or line on the dial. This can be done either by running water from the outlet of each meter until it has the test hand at the proper position, or the register can be turned around in the case until the test hand stands on the line.

When testing one meter at a time with calibrated tank or with scales having percentage beams, the test flow should be stopped when the meter has indicated the passage of the test amount. The percentage fast or slow of the meter can then be read direct from the tank gauge or from the percentage beam of the scales.

When testing several meters in series or when using scales or tanks without percentage markings, the flow should be stopped when the test volume of water has been run into the tank. The percentage fast or slow of the meter or meters can then be computed by dividing the meter readings by the actual amount of water. It will be seen that the computation will be much simplified if the amount of water is one, ten or one hundred gallons or cubic feet. Thus the divisor is one, which makes the meter reading direct in percentage of accuracy. Example: 100 gallons run through the meter; meter reading 96 gallons; meter accuracy 96%, or the meter is 4% slow.

Amount of Water for Tests

All test amounts except on lowest flow or "sensitive" tests should be at least enough to correspond to one complete revolution of the test hand on the meter dial. Often the test hand pinion is not in the center of the circle on the dial and this would introduce an error in reading with partial turns of the test hand. Common practice is to test on the small flows with an amount representing one revolution and on large flows with an amount representing ten revolutions of the test hand. On the other hand, it is possible to get an accurate test on a ⅝ inch meter with ten gallons or one cubic foot and many meter shops do not go beyond this. Of course the greater the amount of water the smaller would be the errors introduced by inaccuracies in readings.

Single or Series Testing

Meters can be tested one at a time or in series. When there are many meters to test there is a worth-while saving in water and time if several meters are tested at once. The number of meters in series or the number of units in the testing machine justified for any condition depend on the number of meters in the system and the frequency of testing. Testing machines or benches for up to 12 meters are in common use.

In series testing the flow can be stopped when the correct amount of water has been run through the meters into the tank, and the accuracy of each meter computed as indicated above. When only a few meters are tested in series it is possible to take advantage of the percentage calibration on the tank or scales by turning off the water when the fastest meter shows a registration of the test amount, reading the percentage accuracy of the meter, starting the flow again and stopping for each meter as it comes up to the desired reading. This method of obtaining the meter accuracy is not considered good practice as it involves changing the rate of flow for every start and stop involved.

Testing with Test Meters

For testing in the field the so-called test meter is convenient and satisfactory if only a rough check is desired. However, a test meter is only a meter and subject to the same variation in accuracy which is characteristic of all disc meters.

Further, a test meter is not positive in the same way as a tank or scales. Testing one meter with a test meter or with any other meter is simply comparing meters and is not recognized in many states which have regulations or laws applying to means or equipment for water meter testing. Field testing can be done much better and more accurately by means of a calibrated testing tank.

Money Value of Meter Accuracy

The accuracy of a water meter is a matter of dollars and cents to the customer and the utility.

Fortunately for the customers, water meters which were originally accurate cannot over-register beyond a slight speeding up in some water conditions. This action is self-limiting, for friction increases with the building up of the disc or piston and tends to counteract the speeding up. Water meters always slow down in service as they become worn, corroded or encrusted.

The intervals at which it is profitable to the water works to test meters and repair them depends entirely on the effects of the water and service conditions in making the meters under-register, on the value of the water taken but not registered, and on the cost of making the necessary tests and repairs. In other words, if the increased revenue from the meter pays a good return on the cost of making the meter accurate, it is simply *good business*.

Several states have recently adopted regulations which specify limits between meter tests in water utilities, both in time and

*From "Testing Water Meters—Why and How," a booklet distributed by Ford Meter Box Co., Wabash, Ind.

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DATE PURCHASED STYLE

INSTALLATION RECORD **TEST AND REPAIR RECORD**

INSTALLED Date	INSTALLED Reading	NAME	ADDRESS	Tap No.	Reason for Removal	Removed Date	Removed Reading	Date	Rate of Test Min. Flow	Rate of Test Inter. Flow	Rate of Test Max. Flow	Repairs Before Test	Repairs After Test	Total Amt. of Water Passed Before Test	Tested By	REMARKS

Heading for a Suggested Form for Meter Record Card. This Can Be Adapted to Meet the Requirements of Any Meter Shop. Actual Size of Card Is 8½ by 11 inches.

in volume of water. These limits are necessarily broad, as the composition of water and its effect on meters varies widely in any state, and many utilities profitably test and repair more frequently than required. These regulations show the growing realization that meter testing *is* important.

The following table shows the value of water unregistered by meters of various percentages of slowness, with various amounts of water drawn through the meter and with water valued at from 10c to 50c per thousand gallons. These figures can be easily transposed into cubic ft. by recalling that 100 cubic ft. equals 750 gallons.

From the table it will be seen that with water at 10c per thousand gallons the return on the investment of testing and repairing a meter 4% slow will be only 40c with every 100,000 gallons of water drawn through the meter. It would take a large and active service to make frequent testing pay under these conditions.

On the other hand, with water at 50c per thousand gallons a meter failing to register 20% of the water passing through it (not terribly rare) would lose $1.00 for the water works with every 10,000 gallons. With these conditions maintained accuracy will pay a handsome return on the investment.

TABLE SHOWING VALUE OF WATER NOT REGISTERED BY METERS OF VARYING PERCENTAGES OF UNDER-REGISTRATION, WITH WATER FROM 10c TO 50c PER THOUSAND GALLONS, AND WITH THREE AMOUNTS OF TOTAL DRAFT.

	Value of Water Per 1,000 Gallons								
	@ 10c			@ 30c			@ 50c		
	Total Volume Drawn—Gallons x 1,000								
%*	10M	50M	100M	10M	50M	100M	10M	50M	100M
4	$ .04	$ .20	$ .40	$ .12	$ .60	$1.20	$ .20	$1.00	$2.00
6	.06	.30	.60	.18	.90	1.80	.30	1.50	3.00
8	.08	.40	.80	.24	1.20	2.40	.40	2.00	4.00
10	.10	.50	1.00	.30	1.50	3.00	.50	2.50	5.00
12	.12	.60	1.20	.36	1.80	3.60	.60	3.00	6.00
14	.14	.70	1.40	.42	2.10	4.20	.70	3.50	7.00
16	.16	.80	1.60	.48	2.40	4.80	.80	4.00	8.00
18	.18	.90	1.80	.54	2.70	5.40	.90	4.50	9.00
20	.20	1.00	2.00	.60	3.00	6.00	1.00	5.00	10.00

*Under-Registration Percent.

Steps in Testing a Water Meter

[A ⅝-inch meter is used as an example. A larger meter would involve the same procedure but would require greater rates of flow.]

1. **Insert Meter in Tester**—Any means of connecting the meter water-tight in the test line is satisfactory but a regular tester is much more convenient.

2. **Flush Meter Out With a Large Flow**—This is to remove air from the meter and line. A flow of ten or more gallons per minute is desirable and should be continued until discharge indicates that all air is out of the line.

3. **Bring Test Hand of Meter to a Mark**—This can be done by stopping the water flow as the hand reaches the mark, or by turning the dial in the meter case if the meter bonnet is removed.

4. **Run a Test at 10 to 15 G.P.M. Running 50 Gallons or 10 Cu. Ft.**—It is desirable to run this much water although more would be just as good or better. Be sure the calibrated tank is empty or the scales balanced before the test flow is started.

5. **Run a Test at 1 to 2 G.P.M. Running 10 Gallons or 1 Cu. Ft.**—Here again the exact amount is subject to variation and more water can be run if there is plenty of time and water.

6. **Run ¼ G.P.M. Test, Running at Least 5 Gallons or ½ Cu. Ft.**—This low-flow test is important for reasons mentioned on pages 9 and 10.

7. **Make a Record of the Tests**—Put down in permanent form the accuracy of the meter at the three rates of flow, date of test and other pertinent information. See suggested record card on the previous page.

IMPORTANCE OF TESTING DISC METERS AT THE CORRECT RATES OF FLOW

By P. S. WILSON

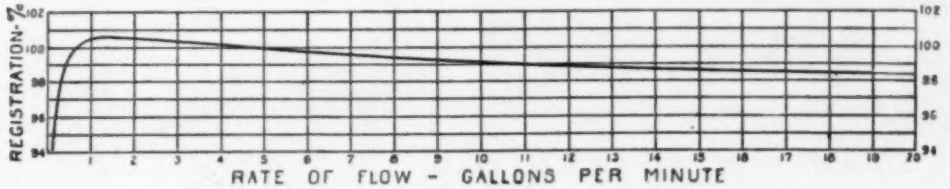
Water Works Consultant, Glen Ridge, N. J.

A TYPICAL registration curve of disc type water meters is shown. In this curve the percentage of the water actually registered during passage through the meter is plotted against the rate of flow in gallons per minute.

The curve as a whole may be shifted upwards or downwards by altering the gearing of the meters but this will not change the general shape of the curve. The curve shown in the figure is drawn for five-eighths inch meters but the corresponding curve for any size of disc meter will have much the same shape in relation to the total range of capacity of the meter. The important fact to observe regarding this curve is the fact that it is a curve and not a straight line. In other words, even above the low flows which the meter will not register, the percentage registered is not the same at different rates of flow.

Importance of Testing at Several Rates of Flow

The purpose of testing a meter is to determine the percentage of the water passing the meter which is registered by it. As explained above, this percentage is normally different at different rates of flow. In routine meter shop practice it is of course impractical to test a meter at every rate of flow under which it will actually operate, and yet we must have assurance that it will register within the limits of accuracy adopted at all of these different rates. We know that a test at a single point on the curve, that is, at a single rate of flow, will not give us the percentage registered at other rates of flow. The curve may be of different curvature depending upon the condition of the meter, and we are making the test because we do not know the condition of the meter. If the clearances in the disc chamber are too great, for example, the meter will not register the low flows well and its curve will drop off too rapidly at that end. If the "control" is not close enough, that is, if the spindle is not held at the proper angle, the meter's registration curve will in all probability go up too high at the intermediate rates of flow. With the multiplicity of parts in a meter there are of course many other defects which may have various effects upon the performance of the mechanism as a whole.



Curve Showing Accuracy of Meter Registration at Variable Rates of Draught.

The endeavor must be to test the meter at the least number of rates which will serve to indicate with sufficient reliability what the performance will be over the rest of its range of capacity. It has been found that in normal practice it is necessary to make a test at each one of the three different rates of flow, unless the condition of the meter is already quite well known. In order to obtain reliable information from as few as three different rates of test, these rates must be carefully chosen in order to show up the true form of the curve and to know that there are no irregularities in it between the points located by the tests.

The three rates of flow at which a disc meter should be tested are usually termed the "Low" or "Minimum" test flow, the "Intermediate" or "Medium" test flow, and the "High" or "Full" flow.

Minimum Flow Test Requirements

The "Low" or Minimum" flow test is made in order to determine that the meter does not drop off in registration at any higher rate of flow than economically possible, in other words, the meter must be able to register down to a certain predetermined low rate with sufficient accuracy. The accuracy of registration at low flows depends to a large extent upon the reduction of clearances and at the same time the avoidance of friction in the meter.

The rates of flow called for as "Minimum Test Flow" in the Standard Specifications for Disc Type Meters as adopted by the American Water Works Association and the New England Water Works Association, and reproduced herewith as Table I, are the rates of flow in common use. Different organizations vary somewhat the required percentage of registration at these flows to suit individual views and conditions. The Standard Specifications referred to call for at least 90 per cent registration at minimum test flows. Good manufacturing methods and skillful repair work can be considerably better than this on both new and repaired meters, 94 per cent or 96 per cent being not unreasonable to expect.

Table I

RATES OF TEST FLOW, FROM STANDARD SPECIFICATIONS FOR COLD WATER METERS, DISPLACEMENT TYPE, ADOPTED BY THE A.W.W.A. MAY 10, 1946.

Size of Meter (Inches)	Normal Test Flow Limits (gallons per Minute)	Minimum Test Flow (gallons per minute)
⅝	1 to 20	¼
¾	2 to 30	½
1	3 to 50	¾
1¼	5 to 100	1½
2	8 to 160	2
3	16 to 300	4
4	28 to 500	7
6	48 to 1000	12

Intermediate Flow Test Requirements

The Intermediate test flow should be chosen so as to ascertain that the registration at the high point of the curve does not go too high. The rates should, therefore, be such as to aim for the probable highest point. This will vary with different makes and types of meters but it will usually be found at, or a little higher than, the lower figure given under "Normal Test Flow Limits" in the Standard Specifications—see Table I. For a five-eighths inch meter the table gives 1 gal. per min. and the test flow should usually be from 1 to 2 gal. per min.

If the meter is geared and fitted so as to maintain a good registration at the low and high flows then the difficulty in most cases will be to keep the registration down at the intermediate flow. The flatter that the curve for the meter is, the less need there is for such practice. This is one of the many things to be considered in selecting a meter.

High Flow Test Requirements

The high flow test is considered by some to be the least important. This is unfortunate because it is the quickest and most convenient to perform. The exact rate of flow to be used at this test certainly is less important than with the low and intermediate tests because at rates of flow above the intermediate the curve is not apt to rise or fall so markedly. Many shops use a high test flow equal to the higher figure given under "Normal Test Flow Limits" in the standard specifications (Table I). For a five-eighths inch meter the 20 gal. per min. flow is approximately the maximum rated capacity of the meter. The practical objection to using this figure for the high test flow is that in very few cases will the service pipe and plumbing in a residence pass nearly so high a rate of flow and we are therefore testing at a rate beyond that at which the meter will ever operate. Between 50 per cent and 75 per cent of this high figure is a more logical one to use for testing in routine procedure. At the high flow the percentage registered should again be kept up, as in the low flow, and a minimum of 98 per cent is often specified in accordance with the standard specifications.

Having given consideration to the reasons for choosing each one of the three different rates of test flow it is of course self-evident that it is of equal importance to actually perform the tests at those rates, in other words, to measure with reasonable accuracy just what the rate of flow is during the test and to adjust it to the correct figure.

TABLE II

Discharge of Orifices in Gallons Per Minute. The Smaller of the Two Figures Given in Each Case Is the Discharge of a Sharp Edged Orifice in a Thin Plate. The Larger Figure Is the Discharge with Properly Rounded Edges

Size of Orifice— Inches	———Pressure—Pounds Per Square Inch——— 40	60	80	100
1/32....	0.11— 0.18	0.13— 0.22	0.16— 0.26	0.18— 0.29
1/16....	0.44— 0.74	0.54— 0.90	0.62— 1.0	0.70— 1.2
1/ 8....	1.8 — 3.0	2.2 — 3.6	2.5 — 4.2	2.8 — 4.7
3/16....	4.0 — 6.7	4.9 — 8.2	5.6 — 9.4	6.3 —10.5
1/ 4....	7.1 —11.8	8.7 —14.5	10.0 —16.7	11.2 —18.7
5/16....	11.1 —18.5	13.6 —23.	15.7 —26.	17.5 —29.
3/ 8....	16.0 —27.	19.6 —33.	23. —38.	25. —42.
7/16....	22. —36.	27. —44.	31. —51.	34. —57.
1 /2....	28. —47.	35. —58.	40. —67.	45. —75.

Importance of Accurately Measuring Flows

The most frequently used means of determining the rate of test flow is with an orifice. No fault can be found with this means if we really know how much water is flowing through the orifice.

The rate of flow through an orifice of a given size depends principally upon the shape of the edges of the hole, the thickness of the plate in which the hole is drilled, and upon the effective pressure acting to push the water through the hole. Rather than to state the size of the orifice it is far more definite to give the rate of flow in gallons per minute, or as the number of seconds to pass one cubic foot, as is done in up to the minute shops.

Table II gives the uncertainties of using orifices which have not been actually tested under fixed and known pressure. For example, a one-sixteenth inch orifice under a pressure of eighty pounds per square inch may discharge as much as one gallon per minute if the inner corners of the hole are properly rounded. On the other hand, if the edges of the hole are sharp and square and the plate through which the hole is drilled is thin the discharge may be less than two-thirds of a gallon per minute under the same pressure. Variations in the effective pressure added to the above uncertainties will of course cause even greater indefiniteness in the discharge. At forty pounds per square inch the discharge of the one-sixteenth inch sharp edged orifice may be considerably less than one-half gallon per minute, while an increase of the pressure to one hundred pounds per square inch will produce a discharge through the same orifice with round edges of over two and one-half times as much. Such uncertainties as these will greatly nullify the benefits of otherwise careful testing.

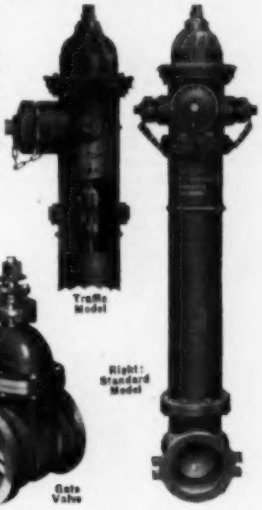
The best way to determine that the correct rate of flow is being used is to actually use a watch, and preferably a stop watch, to time the filling of a calibrated can or tank. The test flows should be stated in terms of definite figures, such as gallons per minute, and not in terms of the size of the orifice or the number of turns of the valve wheel.

The figures given in Table II are the theoretical figures as to the discharge in gallons per minute of different sizes of orifices under different pressures. The smaller of the two figures given in each case is the discharge with a sharp edged orifice in a thin plate, or with the edges properly bevelled on the outlet side. The larger figure is the maximum discharge to be expected with properly rounded edges on the inlet side of the orifice. These figures may serve as a guide in the choice by trial sizes of orifices to be used for obtaining certain rates of discharge. Actual measurement and timing should be employed to check each one, however. It must be remembered that the pressure which is effective upon the orifice will only be shown correctly by a gage located next to the orifice, and beyond the meter being tested, also that the pressure reading must be taken after the flow has become steady and constant.

M & H VALVE AND FITTINGS COMPANY

ANNISTON, ALABAMA

The letters M & H are the sign of quality on Valves, Hydrants and Pipe Line accessories. High quality materials, simplicity of design and expert workmanship have established for M & H enviable reputation for dependable service in the water works and sewage fields and for industrial uses. M & H products are modern in design, with many exclusive M & H features.



M & H VALVES AND FIRE HYDRANTS

M & H A.W.W.A. Gate Valves are furnished double disc, parallel seat, iron body, bronze mounted, non-rising stem, or outside screw and yoke. Available spur or bevel geared and with enclosed grease case, also hydraulically or electrically operated. Sizes 2″ to 30″. Low Pressure Valves and Square Bottom Valves are an established part of the M & H line.

M & H Compression Type Hydrants conform to latest specifications of the American Water Works Association. They are available either in standard or traffic models. Hydrants with 5¼″ and 6¼″ valve opening are listed and approved by Underwriters Laboratories of Chicago and Associated Factory Mutuals of Boston. Hydrants with 4¼″ and 4½″ valve opening are A.W.W.A. approved only.

Outstanding features include dry top, easy to lubricate, revolving head. Can be lengthened and working parts completely removed without digging up hydrant.

FILTER PLANTS & SEWAGE PLANTS

Hydraulically and electrically operated M & H Valves are used in sewage treatment plants, water works, filter plants, etc., to save time and labor since these valves can be operated by remote control for quick, easy closing or opening. They are also used as emergency valves to admit higher water pressures into the mains in case of fire. Sizes 2″ to 30″ A.W.W.A.

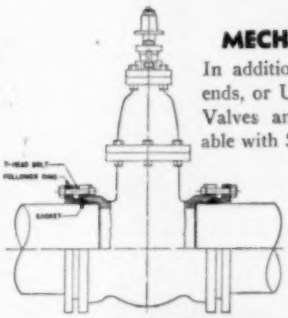
M & H Flap Valves and Shear Gates are iron body, bronze mounted, used in Filtration and Sewage Disposal Plants.

Hydraulic Gate Valve

Low Pressure Gate Valve Rising Stem

Low Pressure Gate Valve Non-Rising Stem

Shear Gate



MECHANICAL JOINTS

In addition to hub ends, flanged ends, or Universal joints, M & H Valves and Hydrants are available with Standardized Mechanical Joint ends for use with standardized mechanical joint cast iron pipe as adopted by the Cast Iron Pipe Industry.

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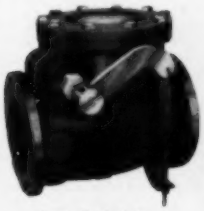
M & H makes a complete line of valves, hydrants, indicator posts and underground pipe fittings for fire protection water systems. All of these M & H products are approved and listed by the National Board of Fire Underwriters of Chicago and by the Associated Factory Mutuals of Boston. All castings therefore are marked "UA—FM."

Rising Stem Gate Valve


Spring Check Valve

Indicator Post

M & H PRODUCTS INCLUDE:

WALL CASTINGS	SPECIAL CASTINGS	TAPPING SLEEVES AND VALVES
CHECK VALVES	FLOOR STANDS	SPRING LEVER CHECK VALVES
EXTENSION STEMS	SHEAR GATES	MUD VALVES
FLAP VALVES	SLUDGE SHOES	FLANGE AND FLARE FITTINGS
FLANGED FITTINGS	B & S FITTINGS	CUTTING-IN TEES

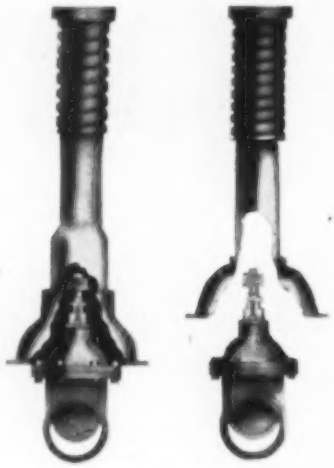
GATE VALVE CARE AND MAINTENANCE

By ROGER W. ESTY

Superintendent, Water and Sewer Board, Danvers, Mass.

TOO commonly, one of the most neglected of the routine operations in a water works system is the care and maintenance of gate valves. In some of the larger cities there are maintenance crews created particularly for this type of work. The crew is generally made up of some of the older men who are experienced in this work, due to their long service with the department or the water company.

They are furnished with a truck equipped with all the necessary tools, wrenches and spare parts, and they may also have built into the truck a mechanical operating device to open and close the gate valves. Smaller towns are more often than not unable to give proper attention to their gates, due primarily to lack of sufficient man-power to do this work and carry on the many other essential activities common to a water works plant.



Valve Box Settings

On the left is a setting as it is pictured in catalogs, and generally installed. To my way of thinking, the method of putting the valve nut-up in the contracted section is improper. On the right is a suggested better way for the several reasons cited in the text. Possibly this may suggest an advantage to be gained in an improved design of this type of box to give better overall service.

My water works experience goes back over a period of 27 years. During that time I have located, measured and plotted onto cards and maps every hydrant, gate valve, and all of the pipe in our system. I have opened and closed every gate valve many times. It was 20 years ago that we first had a water waste survey made of our system and, as many know, this necessitates the opening and closing of essentially every gate valve in the system. This type of work we have continued every second year since, which affords added opportunities of locating and operating all of our gate valves.

Main Flushing Reveals Gate Valve Conditions

Occasionally our piping system is entirely flushed out, street by street, and this again means the operating of nearly every gate valve, and some have to be opened and closed several times during this flushing operation if properly conducted.

From this work experience is gained in the knowledge of what to expect of gate valves and the remedies that are used in perfecting their operation.

Stiff Operation a Main Trouble

One of the main difficulties, if not the main difficulty, we find with gate valves is that they turn hard. As years go on, if such valves are not operated occasionally they become more difficult to operate and in some cities and towns it takes two men, or even as many as four and six men, to close down a gate valve even during a testing period.

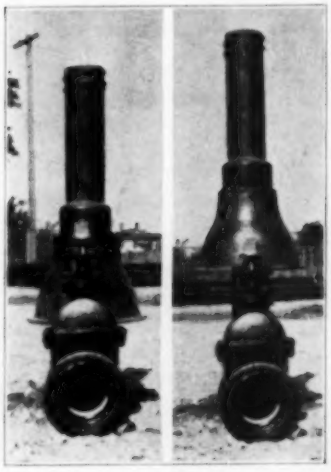
My experience does not go beyond a 20-inch gate valve, but it seems to me that the same principles and characteristics are applicable to all sizes.

A great deal of the indifference toward gate maintenance can be traced to the swivel chair operator. By that I mean the man in charge of the water works who has never experienced the opening and closing of all of the gate valves in his system. If he made tests of his system, such as a water waste survey, and had to work all night opening and closing these gate valves himself, he would soon issue an order to do something about making them operate easier. But generally, it is below his dignity to leave his swivel chair to do this type of work, to find out first hand the physical condition of his system. He doesn't care; he doesn't have to operate them; let the men do it, even if it does take two, four or six to do the job.

The Remedy

What are the difficulties we encounter; what causes them, and how can they be remedied? Why should it take four men to close a gate valve when one man should do it?

Why do stems get bent and broken? What is the cause of all this? Is it because the mechanism is not correct in design, or that the mechanism is not made heavy enough? I feel that the manufacturers as a general rule put on the market a gate valve that will meet all reasonable conditions according to our water works standard specifications. However, I do think the manufacturers do lose sight of one very important factor, and that factor is the packing, and in my opinion, if improper or



A photographic attempt to indicate the advantage of setting the box bonnet higher, giving more clearance between box walls and nut and stem of the valve. The usual setting (left) is in truth a "rock trap," while the other permits rocks to pass by; also makes for easier key connection with the nut should the box become off-center.

neglected packing is not the direct cause, it is at least the seat of 90 per cent of all gate valve troubles.

Many ask, why does the packing have such an important bearing on the ease of operation of the gate valve? Well, the packing gets dry and hard as the years go on. This dry packing acts as a brake on the valve stem.

Take, for instance, your automobile—the brake linings are dry and the brake drum of the wheel is smooth and dry. When the pressure is exerted against one another it creates friction, and

Danvers' Alemite Lubricating Outfit Servicing a Geared Valve.

this friction creates your braking or stopping power. Sometimes at high speeds this friction actually locks the wheels and causes fatal accidents.

On the other hand, pack the brake drums with grease and then attempt to stop your car. The grease eliminates the friction, therefore there is no friction created to stop your car.

Take a rope and wind it around an inch pipe three or four times and draw it tight and then attempt to turn the pipe. You will find you can't do it. Then grease the rope thoroughly and you will find that you can turn the pipe very easily. Try it for your own satisfaction.

Did you ever try holding an eel in your hand? If you have, you probably found that it was nearly impossible to hold it because it was so slippery. If you can get your gate valve stem and packing in the slippery condition you find the eel, you'll have no more hard turning gate valves.

However, there is a difference in the mechanism in some of the gate valves and one make may operate a little different than another make when new. But on the whole, modern gate valves should operate more or less in the same easy manner.

A Case of Proof

Several years ago, while making a water waste survey during nights, we came across a 12-inch gate most difficult to operate. It took the combined efforts of two of us to open and close the gate. The next day I had the gate dug up and repacked. It seems hardly believable, but it could then be turned with just one finger against the cross-bar of the gate key.

Such ease of operation surely saves breaking or bending the valve stems and makes the operation of the gate a pleasure instead of a dreaded job.

Some Packing Pointers

On many of our gate valves and nearly all of our hydrants we have removed the original braided packing and inserted a metallic plastic packing, with two or three strands of flax string type packing on top to keep it from squeezing out when the packing gland is tightened down.

After taking out all of the braided packing, we squirt down around the stem near the packing plate some kerosene or light lubricating oil. We then fill up the stuffing box with a metallic packing that comes in a loose plastic form or in string form. We then put on the stuffing box follower and tighten it down. We then open and close the valve a few turns and then tighten it some more. If it needs a little more packing we insert some and go through the operation again. This method has solved our packing problems and made hard turning gate valves easy turning, and makes fun out of a disagreeable job.

The Larger Valves

In the large gates we drill a hole through the packing plate and insert an alemite fitting. These gate valves still have the braided packing in the packing box. By connecting a grease gun to this fitting we can apply by means of our air compressor about 3,500 pounds pressure and this forces the grease in and around the stem and packing and does a very satisfactory job of lubricating.

It does such a good job on these gate valves that it is a monotonous one man job of opening and closing the valve when testing; in fact, a boy 10 years old can operate the valve.

Large gate valves should have an ample size manhole constructed around them so that a man can get down to the gate and repack it. Smaller gates can be handled more economically by using a 5¼ or 7-inch valve box over the gate with the cover flush with the road.

The gears of a geared gate should be enclosed in a housing with the gears running in oil. If the gears are not housed then they will collect rust and dirt in between the gears or teeth,

Danvers' Method of Marking Street Gate Locations. Yellow figures stenciled on black field on nearest pole.

making them fit tight and bind, causing the gate to operate hard. Dirt falling down into the hole when the cover is picked up causes some of this trouble.

We have eleven 20-inch open geared gates and we wish we had purchased the oil enclosed style. That surely was an error on our part, but our experience with them has taught us to advise others to buy the oil enclosed style.

We have constructed a shield that fits over the gears and the operating nut and fastens to the bolts holding the stuffing box to the bonnet of the gate. This has proved very satisfactory and the dirt does not get into the gears. This gives us the opportunity to keep them well greased.

Improper Valve Box Setting

Many gate valve catalogues show what, in my opinion and experience, is an improper method of setting the box over the gate. Pick up any catalogue and turn to the gate box section

showing the 5¼ or 7-inch box. You will notice that the base or pot sets down over the top of the gate so that the base of the box is even with the flange in the center of the gate. Then the upper section, or middle section, is set onto the base, leaving the operating nut up in this section.

My contention of it being an improper setting and causing maintenance troubles is that if rocks do get into the boxes (and the kids sure do put them in sometimes), that the rock cannot go down past the operating nut. It gets wedged in so hard sometimes that it is impossible to get the key onto the operating nut, and if you do, you cannot turn it. If the box is pushed to one side slightly, the box then comes up against the operating nut and prevents putting the gate key onto the operating nut.

If, on the other hand, the base or pot is set so that the base is up at the level of the stuffing box plate, rocks then can roll to one side into the base, and if the box is tipped there is a greater possibility of getting the gate key onto the operating nut.

In my opinion, box setting is a very important part of your gate maintenance work.

Location Records

Location plans of gate valves should be carefully prepared and measurements should be taken from permanent benches, such as to other gate valves, hydrants, catch basin grates, manhole covers, curbs, etc., and not from telephone poles, trees, walls, fences, etc.

These measurements should be on cards and on sheets in bound books for quick reference. Each should have a number and these can be painted on the underneath side of the valve box cover if desired.

Stencilling of measurements onto buildings, poles, etc., are helpful for quick locating. Numbers can be nailed onto poles or buildings that will stay on as long as the pole or building remains in place. We paint a black square on the reference object and nail on the metal numbers that have been sprayed with an orange colored paint. The contrast makes it conspicuous from any other type of marking.

Removing Recalcitrant Box Covers

Sometimes the gate box cover gets sealed in with tar, or in the winter is frozen in. This can be very easily overcome by pouring a little gasoline on it and setting it on fire. In a few moments the cover can be easily removed.

Quite often it is found difficult to close the gate tightly. This is generally caused by tuberculation in the valve guides and seat. By opening and closing several times this incrustation breaks off and the velocity of the water between the gate and the seat of the valve will most always flush out, allowing the gates to eventually properly seat and closing off entirely the flow of water.

Gate valve work is not expensive. It is a tedious job but can be made very interesting by the various things that have to be done, such as checking measurements, marking poles or buildings, opening and closing, repacking, and the resetting of the gate box at higher elevation.

If a few of these suggestions are followed, most of your gate valve worries will be a thing of the past:

Good plans and measurements.

Stencilled or metallic reference numbers on poles, buildings, etc.

Gate box covers flush with the surface of the ground.

The base of the box well above the center flange of the valve.

Opening and closing each valve on a yearly schedule.

Last, and the most important, proper packing and lubrication.

And a good motto is:

"More turning of gate stems and less of swivel chair stems."

"Know your gate valves!"

Block and Tackle Chart

Here is a chart that will be found useful for determining safe loads and proper loads in connection with ordinary block and tackle.

By laying a straight edge across the chart, as indicated by the dotted line, the pull necessary to lift any weight up to 200,000 pounds is immediately given in column B.

This chart takes into account the friction of the ropes and pulleys, which is less for a smaller number of ropes, although the pull on the lead line is decreased if a larger number of ropes are employed.

For example, what pull on the lead line is required to lift 20,000 pounds with five ropes?

Solution: The graduation corresponding to 5 in column A is connected by a straight line with that corresponding to 20,000 pounds in column C. The straight line intersects column B at approximately 4,700, which is the pull required.

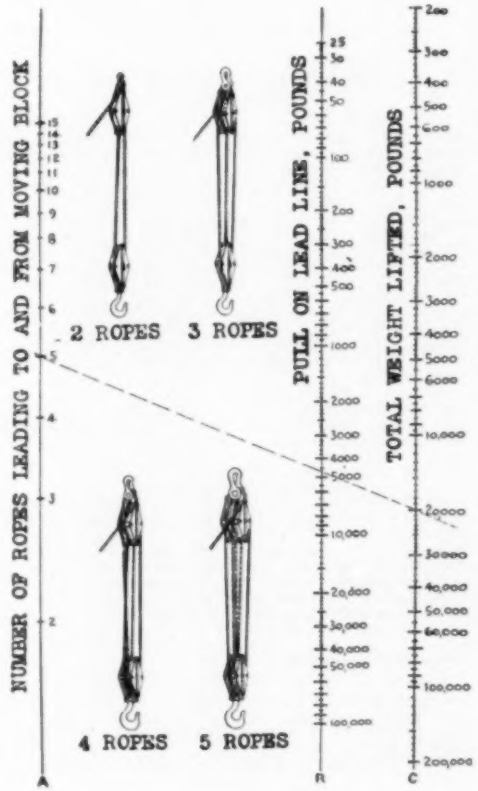
The number of ropes supporting the load and used in column A is determined by counting the ropes leading to and from the moving block as illustrated by the sketches.

In arriving at the stress in the lead line, the common practice is to divide the weight of the load by the number of ropes supporting it, but this is not correct as it does not take into account the friction of the blocks or the rigidity and internal friction of the rope. The maximum stress when hoisting occurs in the lead line, since this besides taking a proportion of load on a single supporting rope also takes the accumulated friction of the blocks and rope in all the other parts of the tackle.

If, for example, a "seven rope" hoist is employed for raising a load of 35,000 pounds, according to the usual practice the stress in the lead line would be computed as 5,000 pounds, assuming that all parts pulled equally. This stress occurs, however, only in the becket line. The maximum stress is 6,325 pounds as determined by test. The chart gives that figure very closely, as will be observed.

Although this chart is based on figures that were determined for wire rope tackle, it is also applicable to ordinary manila rope.

It must be remembered, when buying a rope for use in a block and tackle, that the rope must be strong enough to resist the "maximum" pull, which is the pull in the *lead* line.



Contributed by W. P. Schaphorst, M. E., Newark, N. J.

COMPRESSED AIR FLUSHING OF SMALL MAINS

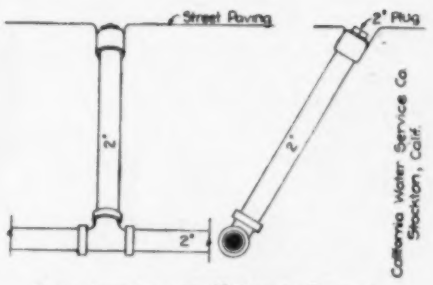
By R. F. BROWN

Plant Manager, California Water Service Co., Stockton, California

MANY water systems in the older California towns, like Topsy, just grew without any suggestion of planning for the future. Stockton was no exception. As a consequence we found ourselves with a great many 2-inch lines in the thinly populated areas.

We have for many years followed the practice of flushing small mains and all dead ends regularly by opening fire hydrants and flusher valves and simply allowing the water to flow from the main under normal pressure of 45 pounds until the main is apparently clear. Under this program all dead ends and all small mains are given ordinary flushing, approximately at intervals of every two months.

This method, however, does nothing but freshen the water in the dead ends and small mains. In order to effect a more lasting cure for taste and odor complaints, we decided to try boosting the pressure in the main with air to attempt to break loose more of the troublesome algae and other deposited material that attaches to the pipe wall. All of our dead ends, regardless of size, and at least every other block of our 2-inch lines have what we call flusher-risers installed for the convenience of our periodical flushing program—see sketch.



RISER CONNECTION TO 2" MAIN FOR FLUSHING

pose and it is economical, because the equipment required is only a portable air compressor and an air storage tank to provide a volume of air under pressure. No expensive cutting of mains or pavement is required and most jobs can be handled with a three-man crew.

When we first started this system we cleaned 40,000 feet of line, mostly 2-inch, over a period of two months. The cost was from 60 to 90 cts. per hundred feet, depending upon the number of services which had to be shut off and turned on again.

The success of this method of flushing is measured by the almost complete absence of the usual recurring taste and odor complaints from consumers served by mains thus treated. It is problematical how soon we will have to repeat this treatment, because from no consumer on the first line so treated has there yet developed a recurrence of complaints.

A secondary result, not anticipated, is the increase in carrying capacity of the 2-inch lines brought about by the loosening and blowing out of a great deal of scale. Thus has resulted a reduction in complaints of poor pressure as well as the taste and odor complaints.

A Self-Told Story

Air Lines Connected (This Time Through House Service at Curb Line)

First 90 Lb. Air Shot. (Note Extension Attached to Flushing-Riser)

First 45 Lb. Water Flush. (No Argument About Need to Eye or Nose)

Clear Water (Shooting and Flush Repeated As Indicated)

Air Flushing Operations

Compressed air is put into the line through a service connection midway between two flusher-risers after we have first closed the shut-off valves on the intervening services. The valve on the flusher-riser is then opened. All water in the line is forced out through the riser, by air under 90 pounds pressure. As soon as the air has expelled all the water from the line it is shut off and water under our ordinary pressure is run through the line to sweep out, through the flusher-riser, all particles of scale, sand or foreign matter that have been loosened by the air "shooting." We proceed in this manner alternately turning into the line air under 90 pounds pressure and water at 45 pounds until the flushing water leaving the risers no longer carries with it any scale or other foreign matter.

This system is apparently successful in accomplishing our pur-

QUICK FREEZING OF SMALL PIPES FOR REPAIRS

By JOHN L. FORD*

WHEN curb valves on water services have to be replaced or when street widening makes it necessary to lengthen the service to the curb valve, it is a big advantage to be able to shut off the pressure. Shutting off the corporation cock at the main generally involves too much digging and expense to be practical unless it is the only way.

In some water works it has been common practice for many years to temporarily freeze water in pipes to serve as a plug in the line and prevent flow during valve changing or other repair and extension work. I recall my father telling how he used a box about 4 in. square and a foot long with notches in the end to slip under service pipes and then fill with ice and salt. The principal requirement for service pipe freezing is stopping the flow during the process, or at least cutting it down to a rate which will permit freezing. In replacing defective curb valves it is generally possible to cut the flow down far enough.

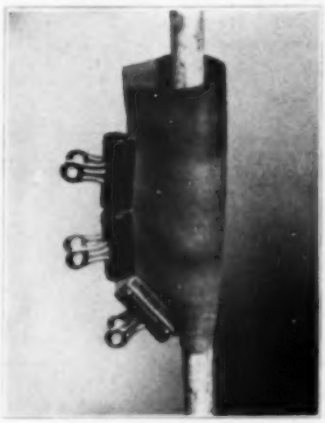
Considering the simplicity and ease of service pipe freezing it has always been surprising that it is not used oftener.

The use of dry ice (solid carbon dioxide) for pipe freezing probably dates from the time when this material first became available. Its principal advantage is that it is so cold that it works amazingly fast. Also it is clean to handle and is now easily obtainable from almost any frozen vegetable distributor or ice cream shipper.

Simple Method of Freezing Service Lines

Here is a quick way to freeze water in pipes with dry ice. The procedure is certainly simple and fast. A piece of old inner tube about 8 in. by 10 in. is centered under the pipe and then brought up and fastened together with wide and strong paper clamps. The rubber should not be stretched tight from end to end but should be a little loose so as to form a pocket around the pipe—see cut.

For freezing a ¾ in. pipe a piece of dry ice about as big as a tennis ball and weighing about one pound is ample. This is placed in a cloth and then pounded into "snow" with a hammer, board or stone. The "snow" is then poured into the rubber pocket and about one-forth pint of alcohol is poured in on top, the two ingredients making a wet mush which is so cold and makes such good contact with the pipe that the water inside is quickly frozen. Any alcohol, anti-freeze or even rubbing alcohol can be used. Gasoline or naphtha are also satisfactory though these may be hard on the rubber. However, old tire tubes can be had for the asking at most service stations so the cost of the rubber makes no difference and gasoline may be more readily available than alcohol.



Suggested Arrangement for Freezing Vertical Pipe

(To make liquid tight joint around pipe press clay, chewing gum or wax into corner between pipe and bottom clamp.)

When the flow in the pipe can be stopped entirely this procedure will freeze the water in a ¾ in. steel pipe solid in from two to five minutes. With a flow of 1/30 gpm. (about one-fourth pint per minute) the flow will stop in about the same time. This flow is more than a drip, coming out of a smooth ended small faucet or small pipe as a steady stream about 1/16 in. in diameter and breaking into drops some three inches below. The experiments on which these results were observed were made with water of about 65° F.; colder water would freeze a little faster. It takes several times as long to freeze a service with dry ice when no liquid is added. Apparently this is because the liquid makes better contact with the pipe and conducts the heat away faster.

In actual work in the trench there may be a small drip from the valve which can be watched to see when the flow stops to indicate that the pipe is frozen.

When there is no leak or drip to watch, the best procedure is to leave the valve closed for five minutes after the dry ice and liquid are poured around the pipe and then open the valve cautiously, keeping in mind that there will be a small amount of water under pressure between the ice plug and the valve which may deceive the operator into thinking the ice plug is not yet solid. If the flow continues, close the valve again before the water thaws much of the ice that has formed, and let the freezing action continue a few minutes longer and again try for flow.

After the pipe is frozen solid it will remain so as long as there is any dry ice left in the envelope and more can be added if desired. After the necessary piping changes have been made the rubber is removed and warm water can be poured on the pipe to thaw it, or a torch can be used. The rubber can be re-used many times and the expense of this method is only 15 cents for material. The time required is only a few minutes in most cases. There is no damage to any kind of pipe by this process, but of course dry ice should never be handled with the naked hand.

If the flow cannot be reduced to about half a pint per minute the pipe cannot be frozen as mentioned above because the warm water passing through keeps a small opening melted through the ice. A longer pocket providing more contact would doubtless freeze a greater flow but it is obviously impossible to stop large flows unless means are available to reduce the leak to a rate that will freeze within a reasonable time.

A Warning

A word of warning should be added about the use of dry ice. The carbon dioxide given off is not poisonous but it can cause suffocation and even death. The small amount used in pipe freezing and the natural ventilation available makes the danger in this work almost negligible. There is little fire hazard with alcohol or gasoline during the freezing because the concentration of carbon dioxide and the low temperature of the liquid prevent ignition.

*Secy. & Treas., The Ford Meter Box Co., Wabash, Ind.

(1) Pound the dry ice into "snow" in a cloth; pour it into rubber pocket around pipe. *(2) Pour about one-fourth pint of alcohol or gasoline on the "snow" and stir to mix.* ***(3) After 3 to 5 minutes the water in pipe is frozen solid; the repair can be made.***

% PROPORTIONEERS %

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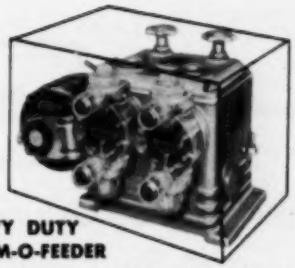
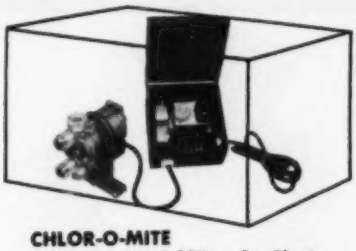
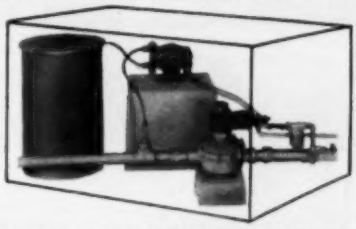
PACKAGES"



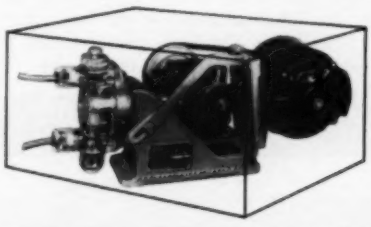
HEAVY DUTY
CHEM-O-FEEDER
Simplex, Duplex, Triplex Models 0 to 30 GPH
0 to 100 psig.



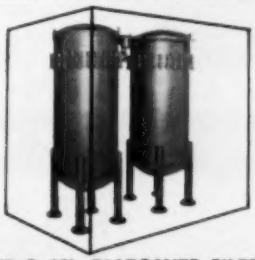
CHLOR-O-MITE
⅛ to 1 GPH 0 to 50 psig.



AUTOMATIC, PROPORTIONAL CHEM-O-FEEDER
0 to 5 GPH 4 to 100 psig.



HEAVY DUTY MIDGET CHLOR-O-FEEDER
0 to 7 GPH 0 to 85 psig.



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%Proportioneers% Equipment is used in water hypochlorination, fluoridation, general chemical feeding, sewage and industrial wastes treatment, chlorine dioxide treatment, and municipal water filtration.

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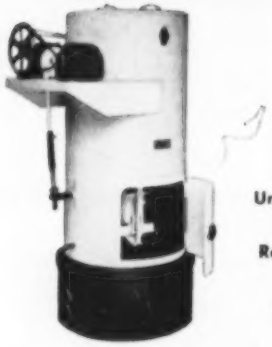

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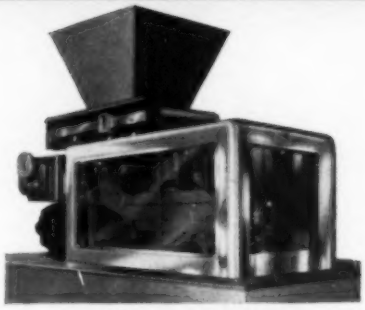
FOR FEEDING DRY MATERIALS BY WEIGHT



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CORROSION CONTROL IN POTABLE WATER SYSTEMS

By ROLF ELIASSEN

Prof. of San. Engr., New York University

Now Prof. of San. Engr., Mass. Inst. Tech.

WATERWORKS engineers are faced with an extensive program of corrosion control in an effort to conserve the huge investment in ferrous metals encountered in water distribution systems and the services of consumers. The great quantities of water used, together with the demand for a low unit cost of water, have led to the search for an effective and economical means of corrosion control.

Research in the field of corrosion of metals has disclosed many of the basic factors which govern the electro-chemical phenomena involved. These researches have led to certain methods of control, many of which are applicable to industrial process waters where cost of prevention and potability are not governing factors. These methods include the use of corrosion resistant metals and alloys involving the elements of copper, nickel, silver, chromium, zinc, and others. Extensive use is also made of the lining of metal surfaces with glass, cement, enamel, plastics, rubber, and other organic materials. The addition of chemicals such as chromates to the water to induce passivity of the metal surface is also used in many industrial water systems.

Effect of Temperature

Temperature plays a vital role in the corrosion of ferrous metals. This is emphasized by the great number of repeated failures in domestic water heaters and tanks. West[1] has shown that in closed systems the rate of corrosion activity is about ten times as rapid at 180° F. as at 50° F. At 210° F. it is ten times the rate at 180° F. If the hot water systems are of the open type so that oxygen and carbon dioxide gases may escape to the atmosphere as the temperature rises, the change of corrosion activity assumes different characteristics. Friend[2] has shown that in an open system, despite the decrease in oxygen concentration with temperature rise, the rate of corrosion increases to a maximum near 176° F., after which it decreases until at the boiling point the rate is practically zero. Most of the domestic water systems in use throughout this country are of the closed type, with little opportunity for the release of dissolved gases. Many systems are uncontrolled to the extent that temperatures rise almost to the point of boiling. The need for additional research on the control of corrosion at the higher temperatures ranging between 150° F. and 200° F. is a vital one.

Dissolved Oxygen Removal

One of the most effective means of preventing corrosion is to remove the dissolved oxygen. Two practical methods of oxygen removal involving deaeration are commonly practiced. One method is to heat the water to a point just below boiling and vent the released gases to the atmosphere. At this temperature the solubility of gases in the water is virtually zero at atmospheric pressure. The cost of heating and subsequent cooling would be prohibitive for large systems.

The other method is to pass the water through an evacuated chamber, either with or without heat being added to the water. Vacuum deaeration could be accomplished without much additional cost at a treatment plant and would protect distribution mains as well as the pipes and equipment of the using agencies. This method of deaeration when practiced by the individual consumer, might involve repumping of the water. Economic studies would be necessary to determine the applicability of these methods of oxygen removal.

Oxygen may also be removed by a process known as deactivation[3]. The water is passed over beds of scrap iron or steel to induce oxidation of the iron and concurrent deoxygenation of the water. Other reducing agents such as sodium sulphite can be used for deactivation. Further treatment is frequently required to remove suspended or colloidal material, thus involving additional expense which must be charged to corrosion control.

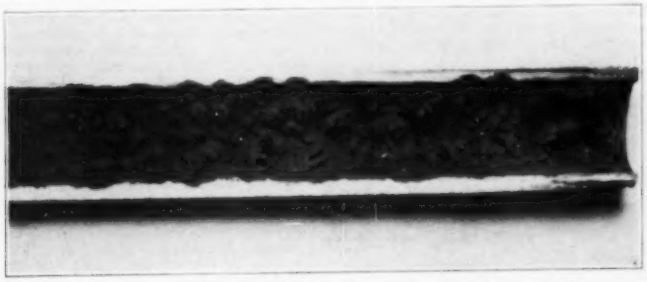
Protective Coatings

Some of the greatest possibilities for the economical solution of the corrosion problem will be found in the provision of protective coatings on the metallic surfaces in contact with the water. Some of the inexpensive coatings have been known to deteriorate with use and cannot be renewed. When this takes place the surface of the metal is exposed to the corrosive action of the water. Zinc coating of pipes, as in the galvanizing process, is typical of the coatings in this category. Other coatings, while they may last indefinitely, may be too expensive for adoption by the water works profession. The ideal coating should be economical and either durable or easily replaceable.

Many attempts have been made to form a calcium carbonate coating on metallic surfaces. This is most frequently accomplished by raising the pH with soda ash or lime. It must be emphasized that increase of pH alone will not assure protection against corrosion in the ranges of pH met with in potable water supplies. Wilson[4] has shown that pH has little influence on the rate of corrosion between the values of 5.0 and 11.5. In this range the concentration of dissolved oxygen in the water is the principal factor influencing corrosion.

Raising the pH may induce the formation of a calcium carbonate scale provided sufficient calcium and carbonate ions are present to form a precipitate. The saturation index of Langelier[5] and the stability index of Ryznar[6] are useful in determining the necessary dosages of chemicals to permit the precipitation of calcium carbonate. The mere existence, however, of conditions which would permit scale formation does not necessarily signify that a protective scale will be formed on the pipe. The indices do not take into account the rate of scale formation. Ryznar[6] states that the "index does not indicate how much calcium carbonate will deposit: whether a state of supersaturation will be present which will be great enough to produce a precipitate; and whether it is great enough to give a protective film."

It is conceivable that the rate of formation of tuberculated surfaces composed of the products of corrosion may be greater than the rate of formation of the coating



Tuberculation—Flow in Pipe Impeded, Usually Pitting Underneath

Pitting—The Result of Localized Corrosion

of precipitated calcium carbonate. In this case little protection will be afforded. Dangers are also inherent in the scaling of hot water heaters and other units in which the temperature of the water is raised. In their extensive studies on control of corrosion at Army posts, Kessler and his colleagues[1-4] have found that the porous nature of the calcium carbonate deposit permitted severe pitting and localized corrosion to take place under the coating. Thus, the value of this approach to corrosion control is open to question, more particularly in hot water systems than in cold water systems.

Research has been conducted by many experimenters with the goal of finding a chemical which might be added to the water in minute quantities to form a protective film over all metallic surfaces exposed to the water. The most important property of the desired chemical is that it shall have no effect on the potability of the water either from the physiological or the palatibility standpoints. The film or coating must be formed after the pipe is in place and be maintained by continuous or intermittent treatment of the water.

Sodium Silicate Films

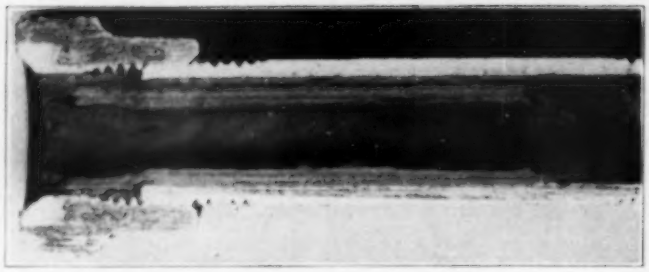
Sodium silicate was one of the first chemicals which research disclosed would be useful in controlling corrosion in potable water systems. Speller and his associates[5] carried out extensive work on the use of this chemical. Their experiments showed that 40 ppm. of SiO_2 would reduce corrosion by 85 per cent in a period of fifteen days with Pittsburgh water at 110° F. Many others have obtained similar results. Stericker[20] attributes the success of silicates to the formation of a film on the surface of the metal by interaction with the ferrous hydroxide formed as the ferrous ion leaves the metal. Formation of the film is usually a slow process requiring about a month in many waters.

It should be underatood that control does not imply complete protection. Usually it involves a high percentage of decrease in the rate of corrosion and tuberculation. Vail[6] explains that the film is a slightly permeable gel and the transfer of oxygen from water to metal does not entirely cease with the formation of the film. The coatings, however, are usually evenly distributed, dense and adherent enough to retain the ferrous hydroxide concentration at the metallic surface sufficiently high to interfere with the passage of oxygen from the water to the metal. The presence of calcium or magnesium salts in the water is believed to facilitate the formation of the coating.

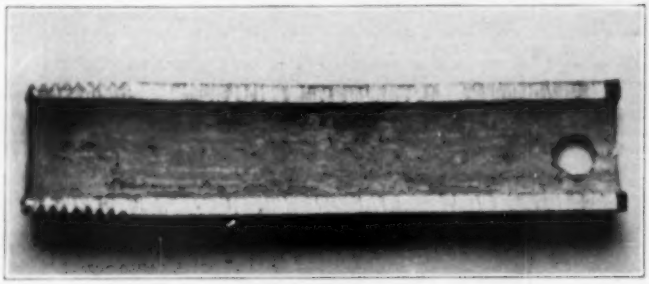
Experience at Army posts[3] has shown that sodium silicate can be relied upon to achieve corrosion control with many types of corrosive waters. For the average water, sodium silicate having the composition $Na_2O: 3.25\ SiO_2$ and a specific gravity of 40° to 42° Baume' has been found most desirable. The pH of the water after addition of sodium silicate should lie between 8.0 and 10.6, the upper limit prescribed for potable water supplies by the U. S. Public Health Service[14]. If a pH of 8.0 cannot be attained by feeding the above silicate, it would be advisable to add a more alkaline silicate such as $Na_2O: 2SiO_2$ or an alkaline compound such as soda ash or caustic soda along with the silicate.

Initial dosages should be in the order of 12 to 16 ppm. (as SiO_2), except in waters high in natural silica, in order to satisfy the high adsorptive demand of the metallic surfaces. After a month, or when a film starts forming in the remote parts of the distribution system, the dosage may be reduced gradually to the point where a residual of at least 1.0 ppm. above the natural silica content of the water can be detected in the far end of the distribution system. The mere presence of residual silicate is not enough to assure the formation of a coating, but the residual is necessary for the coating to be developed and retained.

Turbulent flow characteristics should prevail in the pipes in order to assure silicates being in contact with the pipe surfaces. Field observation of the metallic surfaces is essential to determine the degree of protection obtained. When the coating has formed, the final rate of feed may be reduced to a value as low as 4 to 8 ppm., or sufficient to maintain the coating at all times. Where water is heated to high temperatures, a greater dosage may be required.



Scaling—Too Much Coating—And Not the Right Kind



Protective Coating Stops Corrosive Action

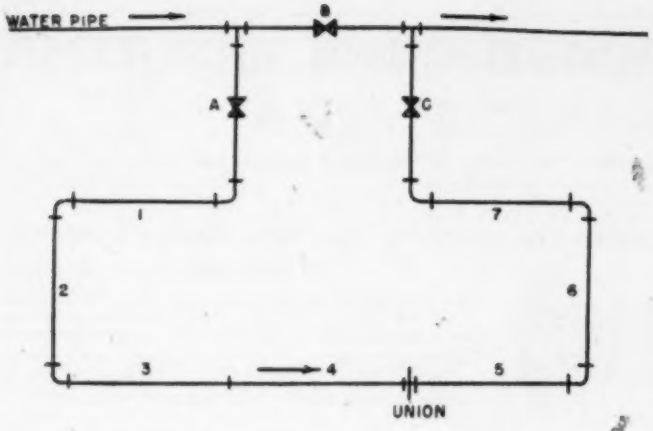
Polyphosphates as Inhibitors

Phosphates of certain types have been recognized as corrosion inhibitors during recent years. The phosphates most commonly used are the molecularly dehydrated polyphosphates known as sodium hexametaphosphate, $(NaPO_3)_6$, and sodium septaphosphate, $Na_8P_7O_{22}$. The formula for the latter may also be written as $Na_2O: (NaPO_3)_7$, showing that it is slightly more alkaline than the metaphosphate, but of similar composition. Hatch and Rice[15] claim that protection is achieved through the formation of a film on the metallic surface by adsorption of the metaphosphate from solution. Formation of the film does not take place rapidly, often taking a month to appear in the remote parts of the water system. It has been shown by Rice[15] that the results obtained will be proportional to the actual total quantity of metaphosphate passing over an area of metallic surface each day rather than the *concentration* of the chemical in the water. For this reason turbulent flow in the pipe is productive of best results.

Once the film is formed, reversion of the metaphosphate to orthophosphate takes place gradually. The latter is not effective in corrosion control. Sufficient metaphosphate must be present in the water to replace the orthophosphate which leaves the metal. The same holds true for the septaphosphates. Control of pH has not been found necessary as the chemicals have proven effective within the range of pH found in most natural waters, from pH 5.2 to 10.6.

As with silicates, the control is not usually perfect to the point of complete protection from corrosion, but the reduction in the rate of corrosion may be extremely high with many waters. This is verified by the report of the AWWA Committee on Water Conditioning Methods to Inhibit Corrosion[16]. After their exhaustive survey of this subject, their conclusions were, "In ferrous metal piping systems, the use of metaphosphates will nearly always eliminate, or at least minimize, the outward manifestations of corrosion, particularly red water and tuberculation." It should be emphasized that the absence of red water alone is not the criterion of corrosion control. Chemists have shown[18] that the polyphosphates will combine with the iron in the water to form soluble complex phosphate ions and thus mask the evidence of corrosion as far as the appearance of the water is concerned. To be considered successful the chemical must form a protective coating which will minimize the loss of metal from the surface in contact with the water.

The author and his associates have utilized the polyphosphates for corrosion control at many locations on the Atlantic and Pacific coasts where corrosive waters



TEST LOOP SHOWING
ARRANGEMENT OF SEVEN 12-INCH TEST PIPES

are prevalent. With steel piping it has been found desirable to start the feeding at a rate of from 6 to 12 ppm. of the polyphosphate. The higher value is necessary where water is heated to 185° F., which is the required temperature for disinfection of tableware. Tests by Morgen and Swoope[15] show that between pH 7 and 9 a good percentage of the polyphosphates may revert to orthophosphates in 24 hours.

As the film develops the dosage may be cut back to the point where sufficient polyphosphate is present in the water to give a residual of at least 0.5 ppm. of the meta- or septaphosphate at the far ends of the distribution system. In some instances the final dosage to secure effective control of corrosion may be as low as 2 ppm. in lines carrying cold water. More generally a dosage between 2 and 6 ppm. is required. Where maximum protection is necessary at 185° F. the ultimate feed may be even higher. Determination of minimum dosage depends upon residual metaphosphate present and observation of actual results on the metals in contact with the water.

Combination Treatments

Polyphosphates and silicates have been added together in some cases of corrosion control where feeding each chemical separately did not give the protection desired. This combination is particularly desirable where the water has a scaling tendency which will lead to clogging of pipes when silicate is used alone. Dosages would be somewhat less than for each chemical alone and can best be determined by experiment. The author has obtained good results using 2 to 4 ppm. phosphate and 8 to 12 ppm. silicate on corrosive waters.

Tetrasodium pyrophosphate has been used successfully in the mitigation of corrosion with dosages (anhydrous basis) similar to those employed with metaphosphates. Some authors[8] have reported on the use of a mixture of pyrophosphate and an organic material derived from the fermentation of certain plant juices. Sufficient experimental data and reports of field experience are not available on the use of either pyrophosphates or organic compounds to determine the conditions under which these chemicals can be used in the control of corrosion.

Proportional Feeding and Test Loops

Proportional feeding of the inhibiting chemicals plays an important part in the success of corrosion control. Hypochlorinators of various types have given excellent results in feeding solutions of phosphates and silicates. These feeders may be either the simple hydraulic displacement type for low flows or the plunger and diaphragm types for higher flows. Frequent cleaning and flushing is desirable in order to prevent clogging of the apparatus. Many other types of feeders can also be utilized, but solution feed at a rate proportional to the flow is recommended for most consistent results.

Test loops provide the most accurate means of checking on the sufficiency of protection obtained in hot and cold water services. It is essential that test pipes of typical metals used by water consumers be installed at critical points served by the water utility, particularly at the ends of the system remote from the point or points of chemical feed.

The accompanying diagram shows a simple layout which permits the pipes to be subjected to the actual conditions of temperature and flow characteristics encountered near the critical point at which protection is desired. The test pipes can be taken down at any time without interfering with the supply of water. As many test pieces as desired can be installed in a loop of this type. The important factor is the periodic observation of the coating developed and the degree to which pitting and tuberculation are arrested. Determination of minimum dosage can only be made by frequent observation and analysis of these test pieces. At the present time there is no other economical method as effective as this easily comprehended scheme in guiding the water works operator in the selection of the treatment or the amount and type of chemical to be used for the control of corrosion at any point in the water system.

Summary

On the basis of experience with many corrosive waters, the author believes that the accompanying table summarizes the average trend of chemical feeds which have given good results. Specific cases may vary appreciably from these average values. Actual control of chemical feed for any particular system must be based upon chemical tests of the water to determine the residual concentrations of the effectual chemicals at the ends of the distribution system. These residuals must be correlated with observations of results on the pipes themselves as evidenced by the examination of test pipes located at critical points in the system.

Remarkable strides have been made in this relatively new approach to the corrosion control problem. Extensive research and correlation of experimental data and field observation still remain to be accomplished before a satisfactory solution can be found for the protection of metallic surfaces in contact with water of any specific chemical makeup. Sanitary engineers should follow closely the development of new compounds for the possibility of application toward the solution of this problem. Analysis of the many different and unusual properties of the newly discovered silica-organic compounds, the silicones, may lead to one or more compounds which will give more positive control than presently obtainable with phosphates or silicates. The goal for which the waterworks profession is striving is the exact answer to the question of how much of what chemicals must be added to any specific water to assure control of corrosion in a particular water system.

Chemical Dosage for Corrosion Control

Chemical	Basis of Analysis	Dosage Initial ppm.	Dosage Final ppm.	Minimum Residual ppm.	Treated Water pH Min.	Treated Water pH Max.
Sodium silicate	SiO_2	12-16	4-8	1.0	8.8	10.6
Sodium hexametaphosphate	$(NaPO_3)_6$	6-12	2-6	0.5	5.2	10.6
Sodium septaphosphate	$Na_8P_7O_{22}$	6-12	2-6	0.5	5.2	10.6
Tetrasodium pyrophosphate	$Na_4P_2O_7$	6-12	2-6	0.5	5.2	10.6

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CALGON TREATMENT*

As Applied in Water Quality Control for the Solution of Four Problems

By OWEN RICE
Calgon Inc., Pittsburgh, Pa.

CALGON is a molecularly dehydrated, glassy phosphate commonly known as hexameta-phosphate and usually given the formula $(NaPO_3)_6$. It is easily dissolved and fed by any solution feed device. For the past ten years it has been of interest and of increasing importance in many phases of water treatment. Its use in several hundred plants during the last six years has shown that the continuous application of small amounts of Calgon to municipal water systems overcomes many of the problems commonly encountered.

Calgon prevents the precipitation of calcium carbonate from lime or lime-soda softened water as well as from hard waters high in bicarbonate alkalinity. Its addition to well water prevents the precipitation of dissolved iron therefrom, while its addition to any water reduces corrosion throughout the system. At first glance, these various applications and effects do not seem related but the result obtained in each case appears to be due to the adsorption of the Calgon on the surfaces of the metals, their metallic salts and oxides involved.

Stabilization of Water After Lime or Lime-Soda Treatment

After-precipitation of calcium carbonate from lime or lime-soda softened water has been a problem ever since the first softening plants were placed in operation. Although after-precipitation can be prevented more or less completely by recarbonation, the limits between which such a treatment must be maintained are very narrow and, although scale may be prevented in this manner, corrosion often results particularly in hot water heaters.

The addition of 1 or 2 ppm. of Calgon completely prevents after-precipitation from lime or lime-soda softened water.[1] It is believed that the metaphosphate is adsorbed on the crystal nuclei of calcium carbonate as rapidly as they form in the water, thus isolating each nuclei from further contact with the water and preventing its growth. This property of Calgon brings about the stabilization of a supersaturated water, from which calcium carbonate would otherwise precipitate.

The addition of Calgon to the water passing to the filters will keep the sand and underdrainage system free from incrustation. In cases where the additional softening effect obtained by the removal of some of the hardness on the filters is desired, the metaphosphate should be added to the clear well. Stabilization with Calgon will result in mains, meters, and hot water systems remaining free from calcium carbonate scale.

Precipitation of $CaCO_3$ from Hard, High Bicarbonate Waters

Calgon has the same stabilizing effect on waters which are naturally hard and high in bicarbonate alkalinity. Where ordinarily the loss of CO_2 or an increase in temperature would cause the formation of scale, this deposition is prevented by the presence of small amounts of Calgon.

Calgon treatment has proven entirely successful in preventing scale formation in hot water heaters with waters up to 1400 ppm. hardness and 600 ppm. bicarbonate, and at temperatures up to the atmospheric boiling point. At the most, an addition of 3 ppm. is required while, under less severe conditions, 2 or even 1 ppm. has proved sufficient.[2]

Preventing Dissolved Iron Precipitation

The action of Calgon on iron in solution is akin to that with calcium carbonate. Precipitation is prevented, thus eliminating "red water." In order to obtain this action, it is necessary to add the Calgon before the iron has had any chance to come into contact with the air. Therefore, in the case of well water supplies it is always best to add the Calgon at the suction side of the pump.

The addition of Calgon in a ratio of 2 ppm. of Calgon for each ppm. of dissolved iron is sufficient to hold the iron in solution even when the water is later aerated or chlorinated.[3]

Corrosion Control with Metaphosphate

Metallic iron when exposed to water dissolves to a considerable extent. Any method of corrosion control depends, therefore, on the formation of an insoluble coating on the surface of the metal.

As mentioned above, Calgon has the ability to coat out on metal or metal oxide surfaces. As the metaphosphate is adsorbed on the iron surfaces of the mains in a distribution system, it forms an iron phosphate film which effectively seals the metal from the water. This film is formed at all pH values above 5.0 so that when using Calgon it is not necessary to add any additional chemicals to change the pH. Also since the film is formed by adsorption and not precipitation, the coating is formed throughout the entire system and not just near the plant.

The addition of Calgon in decreasing corrosion is in no way due to reaction with the water. The water simply acts as a carrier to bring the Calgon in contact with the metal or oxide surface upon which it is adsorbed. Since it is the adsorption of the metaphosphate on the surface of the metal which prevents corrosion, the necessity of supplying sufficient Calgon to meet the requirements of the system is obvious. This can be done either by using a relatively high concentration of Calgon in a small quantity of water or lower concentrations in larger quantities of water. This latter condition is the one which exists in all but the smallest municipal water systems.

In cases where corrosion is severe, it has been found that high initial feeds of Calgon—5 to 10 ppm.—are very helpful in more promptly forming the protective coating in the system. After equilibrium has been reached and the protective coating has been formed, the Calgon can usually be reduced to very small amounts, 1 to 2 ppm., and still be sufficient to maintain the protective coating initially formed.[4]

Summary

Calgon is easily dissolved and fed by any liquid feeding device. It is inexpensive because of the small quantities required and is easy to control. It has proven entirely successful when used in each of the above mentioned applications. Excellent results have been obtained in preventing the after-precipitation of $CaCO_3$ from lime or lime-soda softened water. Hot water heaters are being kept free from scale when hard high bicarbonate waters are used. Dissolved iron has been kept in solution, and the film of metaphosphate formed on the metal surfaces in the system has successfully prevented corrosion and all at concentrations of only a few ppm.

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[*A summarial statement prepared for the Reference and Data Section of *Water and Sewage Works* by Mr. Rice at our request.—*The Editors*.]

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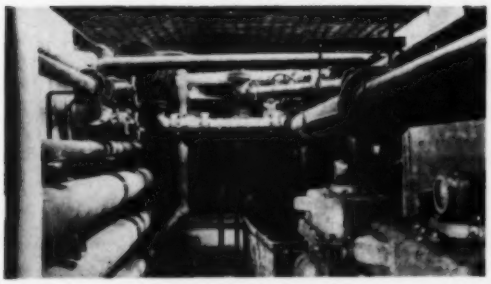

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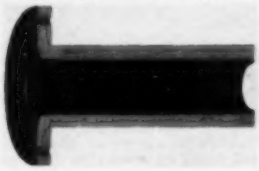

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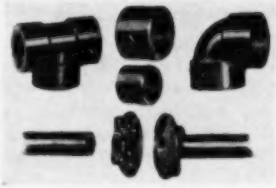

ACE RUBBER LINED VALVES

GATE VALVES, hard rubber lined available in sizes 2" to 12" inclusive except 2½" size.

DARLING GATE VALVES, hard rubber lined, with special metal trim for the required service. In sizes 2" to 20" inclusive.

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DIAPHRAGM VALVES, rubber lined, sizes from 1" to 6" inclusive. (Hills-McCanna Co., Saunder Patent.)

56 PAGE CATALOG →

Covering all types of Ace Rubber Protected Equipment, available upon request. You'll want this reference when specifying maximum corrosion resistance and *longer* equipment life with Ace protection. Write also for the Ace Saran pipe and fittings bulletin.

THE ANTHRACITE EQUIPMENT CORP.

Anthracite Institute Building
WILKES-BARRE, PENNA.

ANTHRAFILT — an Improved Filter Medium

Trade Mark Reg. U. S. Pat. Off.

Address sales and technical inquiries to

Palmer Filter Equipment Company, 822 E. 8th St., Erie, Penna.

Anthrafilt and Its Application

Anthrafilt is made from a **selected** Pennsylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthracite and sand and saves on freight and handling charges.

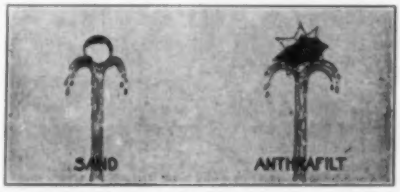
Filtration Characteristics

Anthracite granules are irregular shaped and of varying densities. Weights run about 53 pounds per cubic foot as against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulses of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effectixe size of .60 m.m. to .80 m.m. the uniformity coefficient is less than 1.75 in all sises. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32"x3/16"
No. 3. Anthrafilt—3/16"x5/16"
No. 4. Anthrafilt—5/16"x9/16"
No. 5. Anthrafilt—9/16"x13/16"
No. 6. Anthrafilt—13/16"x1-5/8"
No. 7. Anthrafilt—1-5/8"x2-7/16"
The above sizes have 20% tolerance.

ANTHRAFILT ECONOMY

When Used in Existing Filtration Plants

Increased capacity with same plant
Decreased volume of wash water
Lower maintenance cost through elimination of ridging, mounding and air binding.

When Used in New Filtration Plants

Lower plant investment
Lower cost per cubic yard
Lower wash water costs
Lower maintenance costs

MODERN PRACTICES IN MUNICIPAL WATER SOFTENING

By S. B. APPLEBAUM, Pres.
Liquid Conditioning Corp., New York

MUNICIPAL water softening started in England about 60 years ago. The first municipal water softener in the United States of the lime-soda type was installed about 40 years ago, and the first municipal Zeolite water softener about 20 years ago.

Since that time the number of municipal water softening plants that have been installed in the United States has grown rapidly, as evidenced by Fig. 1.[1] This growth is caused by a greater realization of the benefits and savings which municipal water softening can provide, as well as the elimination of difficulties which the hardness of a water supply causes to the citizens of a community using it for household and industrial purposes. It is predicted that by 1950 there will be over 1,000 municipal water softening plants in the United States of both the lime-soda and the Zeolite type.

The hardness to which waters are softened in municipal plants is gradually being reduced. Not too many years ago it was considered good practice for a city to deliver a water of a hardness of up to 10 grains per gallon, or 171 ppm, as $CaCO_3$. Today municipal water softening plants are aiming at much lower figures, down to 3 to 5 grains per gallon, or 51 to 85 ppm.

W. D. Collins made a study of the municipal supplies in the United States of over 600 cities, and Table I[2] shows the population, in thousands and in per cent of the total, that was served with water of various amounts of hardness in 1932. Table II[3] gives the same information for Canada as studied by Leverin in 1938.

These tables indicate that the trend is towards a softer water for municipal application but that there is still opportunity for future installations of water softening plants where the hardness of the raw water exceeds about 120 ppm as $CaCO_3$.

Benefits from Municipal Water Softening

Soap Saving

W. H. Hudson made an interesting study comparing the cost of soap and other detergents in communities using hard water with their cost in communities using soft water. The hard water cities studied were Bloomington, Urbana and Chicago Heights, Illinois. These were compared with a soft water community, Superior, Wisconsin. Fig. 2[2] shows the annual cost of soap per capita, assuming soap at 16c per pound in these communities, plotted against the hardness.

The reason more soap is used in hard water communities is that the hardness reacts with the soap to form insoluble soap curds. These curds have no lathering effect and represent a wastage of soap by the hard water. The lather, which is desired when soap is used, can only be obtained after all of the hardness in the raw water has been consumed in making these curds. In this way the soap acts as a water softening chemical. When all of the hardness has been destroyed, additional soap used forms the lather.

Troubles Caused by Soap Curds

In addition to wasting soap, the curds formed are very objectionable. They are present as a milky-white precipitate in the water used in contact with the soap. This is apparent when taking a bath in hard water. Perfectly softened water in a bathtub stays clear, and the soap employed makes a luxuriant lather that floats on top.

Curds also form the well-known bathtub ring which is hard to clean and disagreeable in appearance. The curds also deposit on hair, skin, etc. That is why so many beauty parlors have installed small water softeners.

In the laundry, curds form deposits on linens, causing them to be yellowish in appearance and also rancid in odor. Soft water not only improves the appearance of the linens but prolongs their life by virtue of the fact that less bleaching is required.

Cleaning of dishes and glassware is difficult in hard water, and the contrast in appearance when using soft water is outstanding.

Saving in Plumbing Repairs

Hard water when used in hot water heaters causes a scale to form which plugs the coils of heaters and requires expensive plumbing repairs. This has been estimated by the Michigan State Department of Health[2] to average about $4 per family per year.

Effect of Hard Water in Cooking

Hard water toughens vegetables. Soft water makes for greater tenderness, better taste and improved color. It also improves the flavor of coffee and tea.

Fuel Loss

Hard water forms scale which wastes fuel. It has been estimated that this waste averages about $1.50 per person per year.

In the case of industrial plants, the scale caused by hard water in boilers not only causes fuel wastage but shutdowns of the boilers for cleaning and tube losses due to burning out of tubes. Consequently, most modern industrial boiler plants install water softeners to remove the residual hardness left in the treated water by municipal water softeners.

Methods for Municipal Water Softening

The two methods which have been used for municipal water softeners are: (a) Cold lime-soda ash process; (b) sodium Zeolite process.

Cold Lime-Soda Process

This method of reducing hardness was one of the first to be developed. It consists of adding lime (Clark process) to react with bicarbonate hardness, and adding soda ash (Porter process) to react with the sulfate and chloride hardness. The chemical reactions involved are as follows (underlined compounds are precipitated):

LIME REACTIONS

Calcium Removal

$$Ca(HCO_3)_2 + Ca(OH)_2 = \underline{2CaCO_3} + 2H_2O$$

Magnesium Removal

$$Mg(HCO_3)_2 + 2Ca(OH)_2 =$$
$$Mg(OH)_2 + \underline{2CaCO_3} + 2H_2O$$

Carbon Dioxide Removal

$$CO_2 + Ca(OH)_2 = \underline{CaCO_3} + H_2O$$

SODA ASH REACTIONS

Calcium Removal

$$Ca\begin{Bmatrix}Cl_2\\SO_4\end{Bmatrix} + Na_2CO_3 = \underline{CaCO_3} + \begin{cases}2\,NaCl\\Na_2SO_4\end{cases}$$

Magnesium Removal

$$Mg\begin{Bmatrix}Cl_2\\SO_4\end{Bmatrix} + Na_2CO_3 + Ca(OH)_2 =$$
$$\underline{Mg(OH)_2} + \underline{CaCO_3} + \begin{cases}2\,NaCl\\Na_2SO_4\end{cases}$$

TABLE I

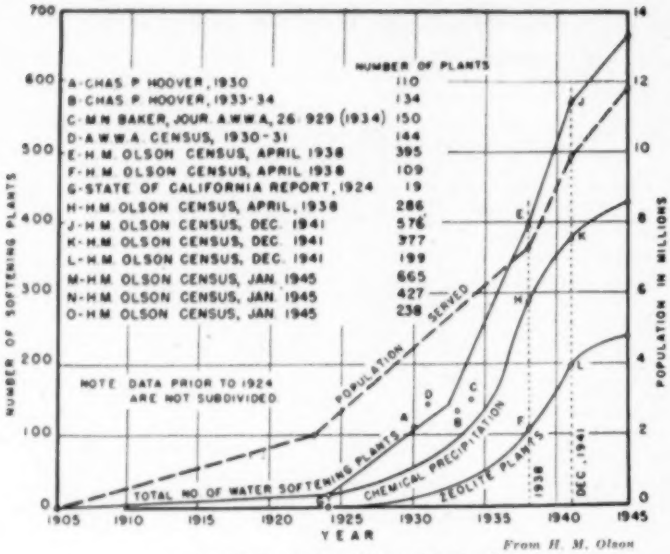
Varying Hardness and Population Served in U. S. in 1932

RANGE OF HARDNESS	POPULATION IN THOUSANDS	PER CENT OF TOTAL
parts per million		
1-60	20,372	29.5
61-120	18,536	26.9
121-180	10,579	15.3
More than 180	7,209	10.4
	56,696	82.1

TABLE II

Varying Hardness and Population Served in Canada in 1938

RANGE OF HARDNESS	POPULATION IN THOUSANDS	PER CENT OF TOTAL
parts per million		
1-60	907.9	16.3
61-120	1,458.7	26.2
121-180	1,057.2	19.0
181+	361.3	6.5
	3,785.1	68.0


NUMBER OF PLANTS
A-CHAS P HOOVER, 1930 110
B-CHAS P HOOVER, 1933-34 134
C-M N BAKER, JOUR A W W A, 26 929 (1934) 150
D-A W W A CENSUS, 1930-31 144
E-H M OLSON CENSUS, APRIL 1938 395
F-H M OLSON CENSUS, APRIL 1938 109
G-STATE OF CALIFORNIA REPORT, 1924 19
H-H M OLSON CENSUS, APRIL, 1938 286
J-H M OLSON CENSUS, DEC. 1941 576
K-H M OLSON CENSUS, DEC. 1941 377
L-H M OLSON CENSUS, DEC. 1941 199
M-H M OLSON CENSUS, JAN. 1945 665
N-H M OLSON CENSUS, JAN. 1945 427
O-H M OLSON CENSUS, JAN. 1945 238
NOTE DATA PRIOR TO 1924 ARE NOT SUBDIVIDED
POPULATION SERVED
TOTAL NO OF WATER SOFTENING PLANTS
CHEMICAL PRECIPITATION
ZEOLITE PLANTS
1938
DEC. 1941
NUMBER OF SOFTENING PLANTS
POPULATION IN MILLIONS
YEAR

From H. M. Olson

Fig. 1. Growth of Municipal Water Softening Plants

Cold Lime-Soda Softeners

The early forms of cold lime-soda softeners were of the intermittent type, consisting of several batch tanks equipped with mechanically driven agitators. One of these tanks was filled at a time, dosed with lime and soda ash, agitated and then allowed to settle quiescently while one of the other tanks was being emptied through a decanter pipe. Filters followed the settling tanks. This intermittent type requires excessive space for the tanks and labor for operation of the various steps described.

The next form developed was the continuous type. The water flowed continuously into the settling tank, where it was mixed with a continuous and controlled stream of the lime and soda ash slurry, while settling of the precipitates took place at the same time. This saved labor of attention. The tanks had to be made large enough and properly baffled so that the velocities employed did not interfere with settling and so that there was a minimum of dead areas and channelling or short-circuiting areas.

The cold temperatures involved, however, interfered with rapid attainment of equilibrium. The precipitates formed were very finely divided and hard to settle. Reactions continued after the water left the settling tank; that is, the treated water was unstable. As a result some of the precipitates continued to form and deposit in the treated water lines and equipment. To stop these after-reactions, carbonation (addition of free CO_2 gas) or acid treatment was applied to the treated water to reduce the pH value by neutralizing the excess of reagent.

Sludge-Contact Reactor

The development of the sludge-contact reactor was a considerable step forward to render the cold lime-soda treated water more stable. The contact with large quantities of previously accumulated precipitates stimulated rapidity and completeness of reaction. This is the modern unit employed in cold lime-soda treatment today. It accomplished, in less than one hour, results equal or superior to those obtained with the old-fashioned continuous unit using four or more hours' retention. Chemicals are saved and a more stable water is produced. So stable is the treated water that some have called these sludge-contact reactors "stabilizers."

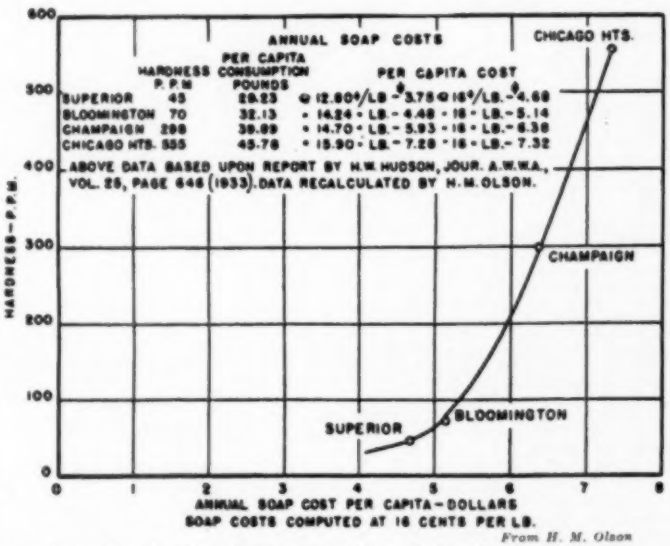
Before the sludge-contact softener was developed, sludge recirculation was practiced by which some of the settled sludge was pumped back to the inlet of the agitator or flocculation chamber. But this frequently resulted in imparting undesirable tastes and odors to the waters especially in the summer when the settled sludge may have fermented.

The development of this type of reactor provided for sludge contact without allowing the sludge to settle. It thus avoided the repumping or recirculation of settled sludge, and also eliminated expensive sludge scraping, or collecting devices. Fig. 3 shows a typical sludge-contact reactor. It combines four functions:

(1) Proper agitation and mixing of chemicals and water; (2) sludge contact with a suspended deep sludge bed (blanket) of previously accumulated precipitates; (3) separation of the sludge from the water as the clear water emerges at the top of the unit; and (4) sludge concentration in internal concentration compartments in order to reduce the volume of sludge blowoff water discharged to waste.

The design *economizes* in space and in chemicals, producing better results in a fraction of the time required by the old-fashioned mixer and settling tank. It is used equally well for coagulation of turbid and colored waters, for softening of hard well waters by lime-soda, or for simultaneously softening and clarifying hard river waters. It is also efficient in absorption problems such as the removing of silica or fluorides by contact with magnesium compounds in the sludge.

In the design shown in Fig. 3, the precipitates formed by chemical addition are not allowed to settle out but are kept suspended by the slowly rotating agitator operating over the entire bottom of the tank. The water and chemicals enter the mixing zone near the bottom at the side where mixing is most efficient because of the relatively high tip speed of the agitator arm. The deflector baffle together with the deflecting blades induces the water to flow towards the central port, through which the sludge and water rise into the clarifying or sludge separating zone. The water then flows radially and outwardly towards the orifices of the peripheral collecting trough. The radially outward travel of the water takes place in the unrestricted clarifying zone at gradually decreasing velocities until a velocity is reached suffi-


ANNUAL SOAP COSTS
CHICAGO HTS.
HARDNESS P.P.M.
PER CAPITA CONSUMPTION POUNDS
PER CAPITA COST
SUPERIOR 45 28.23 @ 12.80¢/LB = 3.75 @ 18¢/LB. = 4.68
BLOOMINGTON 70 32.13 " 14.24 " LB. = 4.48 " 16 " LB. = 5.14
CHAMPAIGN 298 35.89 " 14.70 " LB. = 5.93 " 16 " LB. = 6.38
CHICAGO HTS. 555 45.78 " 15.90 " LB. = 7.28 " 16 " LB. = 7.32
ABOVE DATA BASED UPON REPORT BY H.W. HUDSON, JOUR. A.W.W.A., VOL. 25, PAGE 646 (1933). DATA RECALCULATED BY H.M. OLSON.
CHAMPAIGN
BLOOMINGTON
SUPERIOR
HARDNESS - P.P.M.
ANNUAL SOAP COST PER CAPITA - DOLLARS
SOAP COSTS COMPUTED AT 16 CENTS PER LB.

From H. M. Olson

Fig. 2. Soap Cost Curve Based on Soap Cost at Uniform Basis of 16c Per Lb.

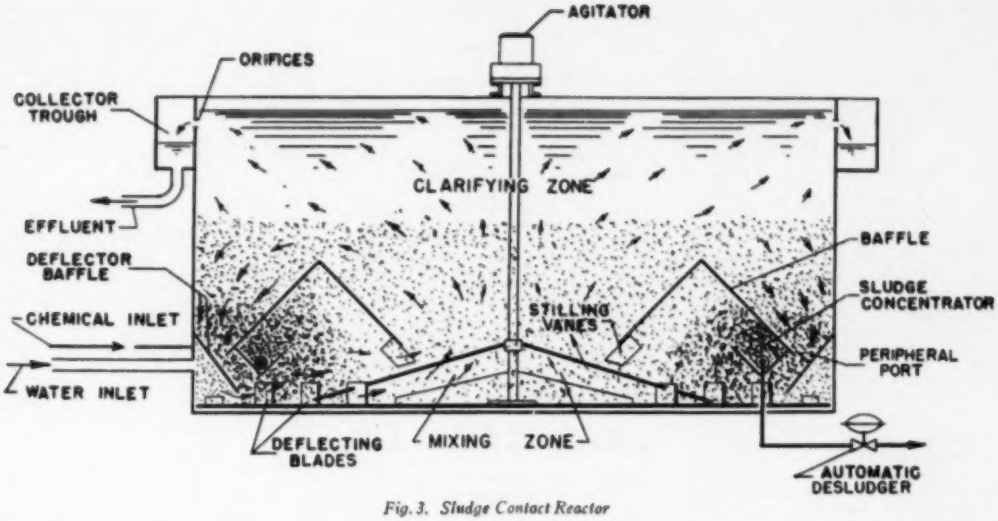


Fig. 3. Sludge Contact Reactor

ciently low to permit efficient separation of the water from the sludge.

Some of the water and sludge recirculate by returning through the peripheral port to the mixing zone. This recirculation ensures complete utilization of the chemicals. The top of the sludge is maintained above the inclined baffle separating the two zones.

Sludge-contact reactor units are built cylindrical in shape for economy of construction and the outer shell can be made of steel, wood or concrete.

Some of the sludge is collected in the sludge concentrator, where it is thickened or concentrated several times as compared with the strength of the suspended sludge bed (blanket). Automatic desludging devices blow off enough of this concentrated sludge to the sewer so that the top of the suspended sludge is kept at the optimum level for the best chemical results consistent with the clearest effluent.

The sludge-contact reactor has three outstanding features:

(1) Positive recirculation of sludge as the arrows indicate so that all of the chemical present is completely utilized and so that there are no dead areas in the tank.

(2) A large, slow-moving agitator operating over the entire bottom of the tank. This prevents any settling out and depositing of sludge on the floor of the tank. It avoids shutting down the reactor for cleaning such deposits or the use of separate sludge scraping devices for this purpose.

(3) Horizontal radial flow, as distinguished from upflow through a sludge blanket, permitting the use of smaller diameter tanks without the danger of sludge carry-over, because sludge particles separate more easily from a horizontal stream than from a vertically upflowing stream.

Sodium Zeolite Process

The sodium zeolite process is one of the most efficient methods of water softening. Essentially it comprises a container having a bed of the zeolite or sodium cation exchange material, supported on gravel or anthrafilt, below which is an efficient collection or underdrain system. As the water passes downward through the sodium zeolite, the calcium and magnesium cations in the water are exchanged for the sodium of the zeolite. When most of the available sodium has been exchanged so that the first trace of hardness appears in the effluent, the zeolite is backwashed and then regenerated or revivified by passing a solution of common salt through it. Sea water, if available, may be employed for regeneration. The excess brine is rinsed out and the unit is restored to service. A meter is provided to guide the operator in regenerating after a definite number of gallons of water has been softened, or to actuate automatic regeneration. The chemical reactions involved are as follows (the symbol Z represents the zeolite):

OPERATING REACTION

$$Na_2Z + \begin{matrix}Ca\\Mg\end{matrix}\left\{\begin{matrix}(HCO_3)_2\\Cl_2\\SO_4\end{matrix}\right. = \begin{matrix}Ca\\Mg\end{matrix}\}Z + \left\{\begin{matrix}2\ NaHCO_3\\2\ NaCl\\Na_2SO_4\end{matrix}\right.$$

REGENERATING REACTION

$$\begin{matrix}Ca\\Mg\end{matrix}\}Z + 2\ NaCl = Na_2Z + \begin{matrix}Ca\\Mg\end{matrix}\}Cl_2$$

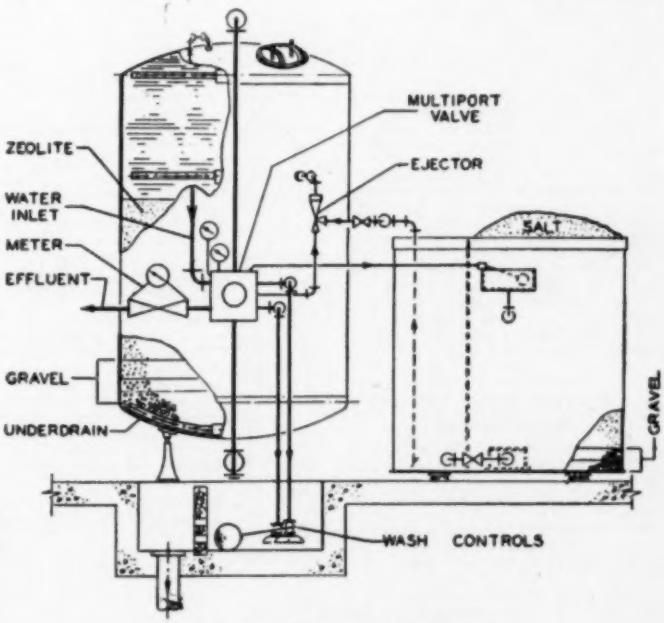


Fig. 4. Zeolite Softener with Multiport Valve

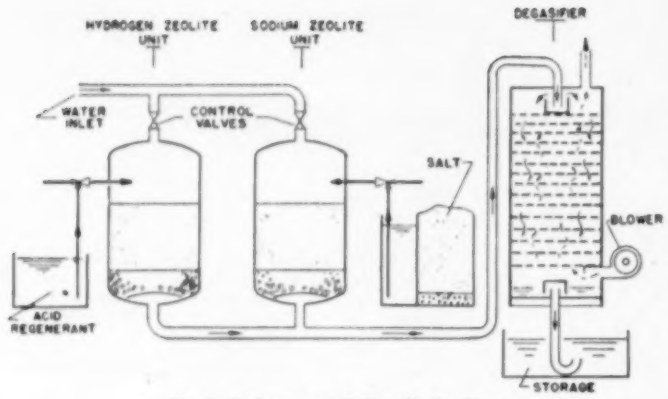


Fig. 5. Hydrogen and Sodium Zeolite Plant

Suitable multiport or individual gate valves are provided to control the operations. The regenerant solution is distributed inside the unit through a perforated pipe system to avoid channelling. Incoming hard water or outgoing dirty backwash water is likewise distributed or collected by a similar pipe system at the top. Fig. 4 shows a standard unit and salt tank with a multiport valve.

Several types of material are available for the sodium cation exchange material, such as glauconite, synthetic gel, and synthetic resin.

Resin, the most modern cation exchanger, is non-siliceous and therefore does not import silica to the treated water. Silica is objectionable for boiler feed purposes. Resin has a high capacity, several times as great as some of the old-fashioned zeolites, and permits higher flow rates per square foot of area.

The softened water produced contains practically no hardness—only 0 to 2 parts per million of hardness expressed as calcium carbonate (ppm. as $CaCO_3$) by the most rigid tests.

Since the usual municipal water softener is not intended to produce a treated water of lower hardness than 3 to 5 grains per gallon or 51 to 85 ppm. (expressed as $CaCO_3$), it is necessary to mix some of the hard unsoftened water with the effluent of the zeolite plant. This is done by bypassing some hard water around the zeolite plant and controlling the bypassed stream so that it is always in proportion to the softened stream. In that way the final mixed effluent will have a constant hardness at any particular figure desired.

If the raw water contains iron or other impurities, it may be necessary to remove these impurities by suitable equipment located on the bypassed pipe.

Comparison of Lime-Soda and Zeolite Methods

There are certain conditions which favor the lime-soda method, and other conditions which favor the zeolite method. A municipality, before deciding on which of these two methods to install in any given case, must compare the advantages and disadvantages of the two methods by making a thorough study of the investment and operating cost, space required, ease of operation, etc., before coming to the final decision.

Advantages of the Lime-Soda Method

(1) The use of lime for removing bicarbonate hardness is usually less expensive than the use of salt to regenerate sodium zeolite softeners. Therefore, if a water is high in bicarbonate hardness, the operating cost for lime treatment will be less than for zeolite.

(2) If the raw water is turbid and needs clarification in addition to softening, the lime-soda method is less expensive to install because it combines water softening and clarification. On the other hand, a clarification plant must be installed to precede the zeolite plant.

(3) If the raw water is polluted, the lime-soda method will aid in sterilizing the water, provided a sufficient time is allowed and the pH value is maintained high enough. The zeolite method does not sterilize the water and would require chlorination for the sterilization. Even in a case of lime-soda municipal water softener, reliance is not placed on the sterilizing effect of the high pH value alone, but in addition chlorinators are employed. The use of the sludge blanket type of lime-soda plant not only helps sterilization by virtue of the high pH value, but the sludge has coagulation and bacterial absorption effects.

Certain boards of health in the United States have required at least 4 hours in lime-soda plants to insure sterilization by the high pH value. This may be necessary for the old-fashioned settling tank where the sludge settles out, but with the modern sludge-contact reactor the bacterial absorptive power of the suspended sludge lessens the number of hours' retention required.

(4) The use of lime to remove bicarbonate hardness, as per the chemical reactions given above, precipitates this hardness, removing it from the water without substituting any other salts in its place. The alkalinity of the original water is, therefore, reduced by the amount of bicarbonate hardness eliminated. This reduction in alkalinity is not accomplished by the sodium zeolite process, because in that process sodium bicarbonate in the soft water is substituted for the calcium and magnesium bicarbonates present in the raw water. The alkalinity in the zeolite treated water is the same as in the raw water.

If the alkalinity of the water is high, its reduction is desirable for many purposes, particularly industrial application, such as for textile plants and boiler plants, etc.

Advantages of the Zeolite Process

(1) The zeolite process can be carried out under pressure by passing the water from the raw water pump directly through a pressure zeolite softener to service. This avoids repumping. Repumping is usually necessary with lime-soda plants.

(2) The space required by the zeolite plant is usually much less than for lime-soda.

(3) If the water is high in non-carbonate hardness, the cost of the salt to regenerate the zeolite is usually less than the cost of soda ash in the lime-soda process. For this reason, in some cases, a combination of lime pretreatment followed by zeolite has been used. This was true of the latest large municipal water softening plant installed near Los Angeles, California.

(4) The handling of salt, dissolving it in a saturated brine in underground wet salt storage basins, is much less troublesome than the storage of lime and soda ash and their handling.

(5) The lime-soda process produces precipitates which have to be settled out and finally disposed of. If there is a very large river alongside, the precipitates or sludge may be discharged into this river without difficulty. Usually, however, objections arise even in the case of fairly large rivers,

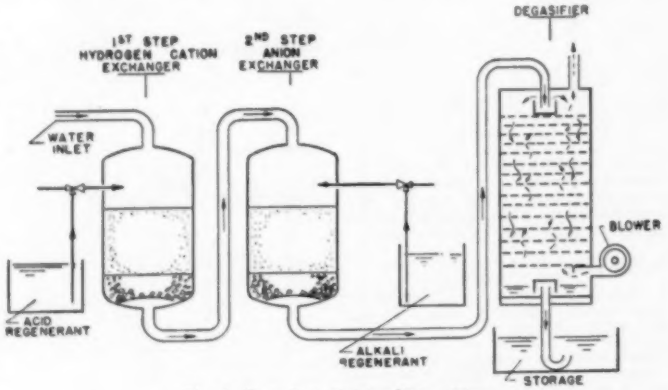


Fig. 6. Two Step Demineralizing Plant

because the sludge settles out to the bottom of the river and, later, during a rainy season, high velocities in the river stir up the settled sludge and carry it downstream, where it may cause complaints from users of the river. In many cases there is no good sized river to receive sludge. The practice then is to collect the sludge in lagoons where it is allowed to dry out in the sun and it is then hauled away. This is a very troublesome operation and it is unsightly. Some work has been done in the last few years to dry the sludge and calcine it to make lime out of it again. This involves keeping the magnesium precipitates separate from the calcium precipitates. It also involves a considerable investment in the lime reclamation equipment. Furthermore, an excess of lime is produced by this reclamation, which has to be disposed of by sale to others.

The zeolite process is free from these difficulties because no precipitates are formed and the waste liquors, during regeneration, contain calcium and magnesium chlorides which are very soluble and flow readily into the sewer system.

(6) The zeolite softeners are usually easier to operate, requiring less skill in their handling than lime-soda softeners.

(7) The zeolite process does not add any objectionable excess of reagent to the water, which may occur with the lime-soda softener if there is any negligence in handling of the lime-soda softener. In the case of lime-soda, too much lime, or too much soda-ash, may render the water too high in pH value.

(8) The zeolite treated water is stable and does not tend to after-react. The lime-soda treated effluent is not *completely* stable even after the use of sludge-contact reactors and carbonation or other means of reducing the pH value, which are frequently employed after the lime-soda plant to increase the stability of the treated water.

(9) The zeolite plant, when operated under pressure, handling a well water free from dissolved oxygen, can produce a noncorrosive effluent because there will be no dissolved oxygen in the treated effluent. This assumes that there will be no exposure of the treated water to the atmosphere.

Where oxygen is picked up, however, or where the raw water contains oxygen, the zeolite treated water may not be noncorrosive, and alkali such as sodium silicate or soda-ash may have to be added to raise the pH value so that there will be a tendency for a slight precipitation to occur in the city distribution system. This precipitation provides a protective film on the inside of the pipe to prevent corrosion due to dissolved oxygen and carbon dioxide. The lime-soda process, as stated previously, provides a treated water of high pH value, which tends to after-react and form deposits in the distribution system. It is, therefore, less likely to cause corrosion and, in fact, the excessive pH value present must be reduced to control the amount of such after deposits formed.

Future Developments

In addition to sodium zeolite there are now available two other methods, namely hydrogen zeolite and demineralizing. These have not yet been applied for municipal purposes, but they have made great progress in the industrial field. The time is undoubtedly approaching when they will receive application for the removal of hardness as well as other dissolved impurities. The hydrogen zeolite is regenerated with acid instead of salt. It removes alkalinity as well as hardness. It, therefore, removes the objection to sodium zeolite previously mentioned. It will find application where acid is cheap and where lime may not be so cheap. It will particularly be preferred where the problem of sludge disposal with the lime-soda plant would be insuperable, and yet where it is desired that the alkalinity be reduced. Fig. 5 shows a typical hydrogen and sodium zeolite plant.

Demineralizing is a two-step process. The water first passes through a hydrogen zeolite unit and then passes through an anion exchange unit. The first unit transforms all the salts into their corresponding acids. The second unit absorbs these acids and produces a water practically free from electrolytes. Fig. 6 shows a typical demineralizing plant. In that respect it is the equivalent of distilled water. For highly mineralized raw waters, demineralizing may find application in the future, not to produce distilled water, which is not needed for municipal practice, but to reduce the sulfates and chlorides to a partial extent and thereby improve a raw water for irrigation and other similar purposes. Sulfates and chlorides are not removable by either the lime-soda or the zeolite processes.

As the demand for higher quality of treated water rises, these newer processes of hydrogen zeolite and demineralizing will, undoubtedly, take their place in municipal water treatment practices.

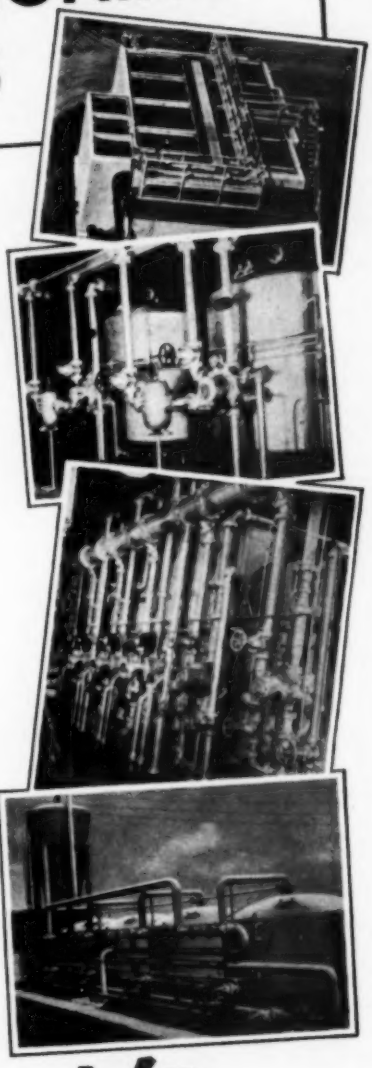
References

1. H. M. Olson. Census of Municipal Water Softening Plants. *J.A.W.W.A.*, 37, June, 1945.
2. H. M. Olson. Benefits and Savings from Softened Water for Municipal Supply. *J.A.W.W.A.*, 31, 607 (1939).
3. Michigan State Board of Health, Bulletin 15.

Metric Conversion Table

Millimeters × .03937 = inches.
Millimeters ÷ 25.4 = inches.
Centimeters × .3937 = inches.
Centimeters ÷ 2.54 = inches.
Meters × 39.37 = inches (Act of Congress).
Meters × 3.281 = feet.
Meters × 1.094 = yards.
Kilometers × .621 = miles.
Kilometers ÷ 1.6093 = miles.
Kilometers × 3280.8093 = feet.
Square Millimeters × .00155 = sq. inches.
Square Millimeters ÷ 645.1 = sq. inches.
Square Centimeters × .155 = sq. inches.
Square Centimeters ÷ 6.451 = sq. inches.
Square Meters × 10.764 = sq. feet.
Square Kilometers × 247.1 = acres.
Hectare × 2.471 = acres.
Cubic Centimeters ÷ 16.383 = cubic inches.
Cubic Centimeters ÷ 3.69 = fl. drams (U. S. P.).
Cubic Centimeters ÷ 29.57 = fluid ounces (U.S.P.).
Cubic Meters × 35.315 = cubic feet.
Cubic Meters × 1.308 = cubic yards.
Cubic Meters × 264.2 = gallons (231 cubic inches).
Liters × 61.022 = cu. in. (Act of Congress).
Liters × 33.84 = fluid ounces (U. S. P.)
Liters × .2642 = gallons (231 cu. in.).
Liters ÷ 3.78 = gallons (231 cu. in.).
Liters ÷ 28.316 = cubic feet.
Hectoliters × 3.531 = cubic feet.
Hectoliters × 2.84 = bushels (2150.42 cu. in.).
Hectoliters × .131 = cubic yards.
Hectoliters ÷ 26.42 = gallons (231 cu. in.).
Grams × 15.432 = grains (Act of Congress).
Grams ÷ 981. = dynes.
Grams (water) ÷ 29.57 = fluid ounces.
Grams ÷ 28.35 = ounces avoirdupois.
Grams per Cu. Cent. ÷ 27.7 = lbs. per cubic inch.
Joule × .7373 = foot pounds.
Kilograms × 2.2046 = pounds.
Kilograms × 35.3 = oz. avoirdupois.
Kilograms ÷ 907.2 = tons (2,000 lbs.)
Kilograms per Sq. Cent. × 14.223 = lbs. per sq. in.
Kilogram-meters × 7.233 = foot lbs.
Kilograms per Meter × .672 = lbs. per foot.
Kilograms per Cu. Meter × .062 = lbs. per cubic foot.
Tonneau × 1.1023 = tons (2,000 lbs.).
Kilowatts × 1.34 = Horse Power.
Watts ÷ 746. = Horse Power.
Watts × .7373 = foot pounds per second.
Calorie × 3.968 = B.t.u.
Cheval vapeur ÷ .9863 = Horse Power.
(Centigrade × 1.8) + 32 = degrees Fahr.
Gravity Paris = 980.94 centimeters per sec.

4 good reasons why Permutit is WATER CONDITIONING HEADQUARTERS



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ECONOMICS OF WATER SOFTENING*

By LOUIS R. HOWSON

Cons. Engr., Alvord, Burdick & Howson, Chicago, Ill.

BECAUSE standards of quality for public water supplies have become increasingly exacting, the water which reaches the consumer in the U.S. today is almost invariably safe, generally clear and sparkling, and usually palatable. And as the quality standards have improved, the public has become more and more conscious of the remaining deficiency of so many water supplies—hardness.

People like soft water. This fact has been capitalized on by a number of forward-looking companies that have organized to dispense soft water service of one type or another. In the most common type the supplier installs a zeolite softener on the consumer's main hot water line, servicing the unit as often as necessary to maintain a supply of soft water. The usual charge for this class of service is from $2.50 to $3.50 a month, or approximately twice as much as the consumer pays for his entire water use. Even at this high cost, however, thousands of public water supply users are availing themselves of softener service in communities where the public supply is hard.

When those who can afford it will buy soft water service at a cost equivalent to a 300 per cent increase in their water rates, no economic justification would seem to be required for softening the entire supply at a cost which ranges from 4c per 1,000 gal. to a possible maximum, for very small plants, of 10c per 1,000 gal.

That water utilities are beginning to recognize their obligation to furnish more than just safe water is evident: in the decade from 1935 to 1945 the number of people in the United States receiving softened water doubled. During that decade more new softening plans were built, and more people were given the advantage of soft water, than in the 30 years previous.

For many years the late H. M. Olson maintained a census of water softening plants (Fig. 1). As of January 1945 Olson

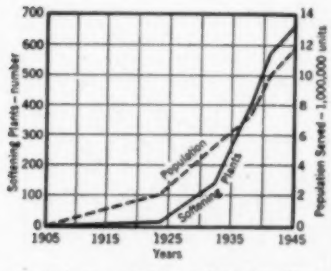


Fig. 1. Increase in Water Softening Plants

Data were gathered by the late H. M. Olson and are not available from 1945 to date; however, the author estimates that approximately 15 million people in the U.S. now receive softened water.

recorded (1) 665 softening plants serving approximately 12,000,000 people with softened water. Complete data are not available on the growth since 1945, but in the author's office alone during that period, softening plants with an aggregate capacity of 186 mgd., or nearly 10 per cent of the 1945 capacity, have been designed. It is probable, therefore, that the number of people in the United States now receiving softened water is approaching 15,000,000.

*Reprinted from JAWWA—Vol. 43, p. 253

Savings Effected

In 1932 Hudson and Buswell conducted a study of soap waste caused by hardness in public water supplies, using as a basis of estimate the cost of soap prevailing at the time (2). These figures, brought up-to-date by T. E. Larson (3) in 1948, are shown graphically in Fig. 2. It may be seen that

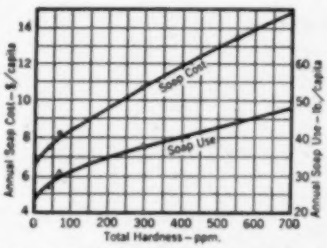


Fig. 2. Soap Waste Caused by Hardness

The average annual expenditure for soap with a water of 285 ppm. hardness is approximately $10.70 per capita, whereas the per capita expenditure for soap with hardness lowered to 85 ppm. would be $8.20, a difference of $2.50 per capita.

the average annual expenditure for soap, in a city with water supply of 285 ppm. hardness, would be approximately $10.70 per capita, whereas the annual per capita expenditure for soap with the hardness lowered to 85 ppm. would be $8.20. The difference of $2.50 per capita applied to an average family of four would amount to $10.00 a year for each family. It must be borne in mind moreover that soap savings are only one of a number of important benefits effected by water softening.

The author recently visited a city whose water supply contained approximately 300 ppm. of hardness and 1 ppm. of iron. Inquiry revealed that approximately 1,000 of the 3,100 water customers had some type of soft water service. Of these it was estimated that less than one-fourth owned their own softeners and that the remaining three-fourths took soft water service from one of the companies operating in the city. It was also found that the cost of softening the water ranged from $2.50 per month for one service call to $3.50 per month for two, with an overall average of approximately $3.00. Those customers who purchased a soft water service received soft water on hot water lines only; in the aggregate, they were paying approximately $36,000 a year for it, an amount greater than the cost of softening the entire water supply of the city. A municipal softening plant could have furnished both hot and cold softened water to all at a cost less than one-third that paid for soft, hot water only. Softening the water would, at the same time, have solved the iron removal problem.

Installation Costs

Construction costs of a number of lime-soda softening plants have been analyzed in terms of current prices based on the *Engineering News-Record* Construction Cost Index, which, using a base of 1913 = 100, currently stands at approximately 530. The results of this analysis are shown in Fig. 3. The data for the diagram—all recent—are based upon actual construction costs and estimates and they indicate that large softening plants, in the 80-mgd. range, can be built for approximately $55,000 per mgd. of capacity at present. This estimate contemplates the softening of well water using filtration rates of 3 gpm. per sq. ft.

The cost per unit of capacity increases for smaller plants. Two 48 mgd. plants, recently contracted for, cost approximately $60,000 per mgd. Plants in the 12-15 mgd. range will cost approximately $90,000 per mgd. capacity; a 2 mgd. plant would cost about $250,000.

The 1951 softening plant construction costs, shown in Fig. 3, are based upon lime-soda plants using either conventional, mechanically cleaned settling basins with 45 minutes slow mixing and 4 hours settling, or suspended solids contact clarifiers with 2-hour detention periods.

Annual Cost

Determination of the type of softening plant, its construction and annual operating cost must be based on a consideration of the specific qualities of the water to be softened. Each plant should be tailored to its individual needs. It is practicable, however, to indicate in a very general way the types of water for which certain processes may be economically adapted. The applicability and comparative cost of chemicals per mil. gal. softened, based upon a water of 515 ppm. hardness, of which 430 ppm.

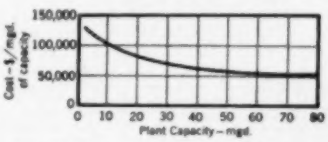


Fig. 3. Construction Costs of Softening Plants—1951

Construction costs of a number of lime-softening plants, of the conventional or solids contact clarifier type, have been analyzed in terms of current prices, based on the E.N.-R. Construction Cost Index 530 (1913 = 100).

are to be removed, are indicated in Fig. 4. The total hardness is shown to vary from 100 per cent carbonate hardness to 100 per cent permanent hardness, with a sulfate content of 100 per cent calcium sulfate in one water, and 50 per cent calcium, and 50 per cent magnesium sulfate in the other.

The cost of salt used in regenerating ion exchange filters, based upon the use of 0.35 lb. of salt per 1,000 grains of hardness removed, is also shown in Fig. 4. The chem-

ical costs used in preparing the comparison were: salt, $15 per ton; lime, $15 per ton; and soda-ash, $32 per ton.

The graph shows that, with 515 ppm. hardness, the lime-soda process offers a lower chemical cost than ion exchange, unless from 75 to 90 per cent of the hardness is of the permanent type. The cost of chemicals varies from slightly over $5.00 per mil. gal. per 100 ppm. of hardness removed to nearly $20. The chemical cost of

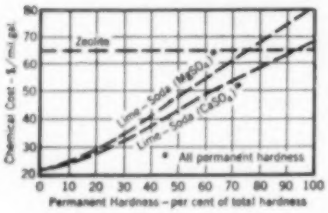

Chemical Cost - $ / mil. gal.
Zeolite
Lime - Soda ($MgSO_4$)
Lime - Soda ($CaSO_4$)
All permanent hardness
Permanent Hardness - per cent of total hardness

Fig. 4. Cost of Softening Chemicals

The applicability and comparative cost of chemicals used to remove 25 grains of hardness from 30-grain hardness water is indicated above. The lime-coda process offers a lower chemical cost than ion exchange unless from 75 to 90 per cent of the hardness is of the permanent type.

removing hardness by the lima-soda process from water in which 60 per cent of the hardness is permanent and, of that proportion 25 per cent is magnesium sulfate, would be approximately $12 per mil. gal. That sum has been used as representative of the chemical cost of softening "average" 285 ppm. hardness water.

Annual costs of softening include: [1] fixed charge on investment, [2] chemicals and [3] labor.

The annual cost of operating plants removing 200 ppm. of hardness from "average" water is shown in Fig. 5. In computing this cost, fixed charges were set at 6 per cent, a relatively high figure for municipal plants but lower than the amount required for a fair return and depreciation allowance for privately owned plants; chemicals were estimated at $12 per mil. gal. per 100 ppm. of hardness removed from raw water of 285 ppm. hardness reduced to

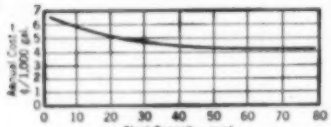


Fig. 5. Estimated Annual Cost of Softening "Average" Water

In computing the annual cost of removing 200 ppm. of hardness from "average" water, fixed charges were set at 6 per cent; chemicals were estimated at $12 per mil.gal. per 100 ppm. of hardness removed; labor costs were estimated from operating records. On this basis, the annual cost of softening was found to be approximately 6.2c per 1,000 gal. for a 6-mgd. plant, decreasing to approximately 4.1c for an 80-mgd. plant.

85 ppm.; the cost of labor was estimated from records of plants in operation. The computation is based on the further assumption that the softening plant will operate at a 60 per cent load factor, that is, that plant capacity equivalent to 1⅔ times the average day's output will be provided.

Under these conditions, the annual cost of softening was found to be approximately 6.2c per 1,000 gal. for 6-mgd. plant, decreasing to approximately 4.1c for an 80-mgd. plant.

The unit costs listed above are based upon the total cost of building a filtration plant to provide for softening as well. When a filtration plant is under consideration, it is usually practicable to take account of softening in the design by providing additional chemical storage and handling and feeding equipment, and by installing mechanical equipment in the settling basins at a cost approximately 15 per cent above that required for filtration alone. If fixed charges on only the additional cost were allocated to softening, the above figures would be reduced by 30 to 40 per cent, and cost of removing 200 ppm. of hardness would then vary from 4.6c per 1,000 gal. for a 6-mgd. plant to 2.9c for an 80-mgd. plant.

Cost to the Consumer

It is not generally appreciated that the cost of softening water to the average consumer is so small. In the average American water works system, 50 per cent of the

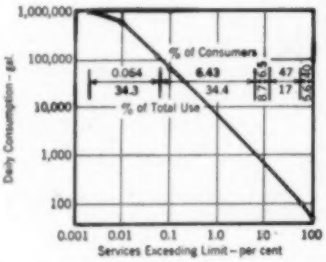


Fig. 6. Customer Classification by Daily Use

A classification system showing the number of customers falling within specific daily use limits indicates that only 10 per cent use more than 800 gpd.

water used is consumed by less than 5 per cent, and frequently by less than 1 per cent, of the total number of customers. As an average therefore, 50 per cent of all customers use less than approximately 3,000 gal. per month each, permitting a low cost for most.

A classification of customers by the average daily use of each is presented in Fig. 6, which indicates that only 10 per cent of customers use more than 800 gpd. per service, or 24,000 gal. monthly.

By combining the data of Fig. 6, giving a classification of customers by use, and Fig. 5, giving the estimated cost per mil. gal. of removing 200 ppm. of hardness, Fig. 7 was prepared. It shows that 50 per cent of the customers who use 3,000 gal. per month or less at a minimum monthly charge of approximately $1.50 would be billed an adidtional 25c for softening.

For at least 80 per cent of the customers, the cost of water softening would be less than 60c per month or 2c per family daily. In almost any city water supply from which 200 ppm. of hardness was removed, 90 per cent of the customers would have their bills increased less than 4c each, daily, 1c per capita, to cover the cost of softening in the utility plant.

The remainder of the cost of softening would be borne by a small percentage of large users—a few large residential users and commercial and industrial consumers—who would have their bills increased approximately 5c per 1,000 gal. or 1¼c per ton.

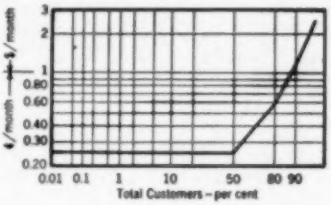


Fig. 7. Rate Increase Effect on Customers

The extent to which customers would be affected by water rate increases sufficient to cover the cost of removing 200 ppm. of hardness is shown to be slight. The additional monthly cost to 50 per cent of all customers would be only 25c.

Clarifiers

With the rapid growth in recent years in the number of softened public water supplies, manufacturers of equipment previously developed for industrial water treatment have adapted their designs to compete with the conventional sludge settling and removal tanks generally used in public water supply softening practice.

There has been much discussion on types of what have come to be known as "suspended solids contact clarifiers," of which there are now at least eight on the market. For the past two or three years, an A.W.W.A. committee, under the chairmanship of H. O. Hartung, has been studying capacity and loadings for these devices.

It is the author's belief that the choice between a conventional and a suspended solids contact clarifier is, in the last analysis, determined by an evaluation of working efficiencies, flexibility and results in terms of cost.

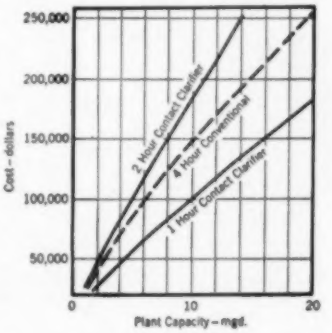


Fig. 8. Comparative Clarifier Costs

The costs of conventional and suspended solids contact clarifiers are based on the E.N.-R. Index of 475 (1913 = 100).

The various manufactures have adopted certain designs, on the basis of which equipment is offered. Competition is keen

and has resulted in the adoption of as low contact periods and as high rates of flow as the manufacturers can safely recommend. In general, detention periods have been reduced to 1—1¼ hours.

The committee, after studying capacity and loadings for more than three years, has reached the general conclusions that this type of installation is particularly adaptable to calcium carbonate precipitation reactions, and that, while it is theoretically possible to produce a softened water chemically stable in calcium carbonate whenever sufficient calcium carbonate surface and time are provided, no evidence has been presented that such chemical stability is generally obtained.

To the committee's general statement the author would add his view that for water with much permanent hardness, particularly if magnesium salts are an important constituent and the supply is drawn from surface sources in the northern part of the United States, detention periods should be considerably lengthened.

Obviously any comparison of costs of conventional and suspended solids contact clarifiers is greatly influenced by the detention period as illustrated in Fig. 8, which compares estimated costs of conventional clarifiers with 4-hour settling periods with suspended solids contact clarifiers with both 1- and 2-hour detention periods. In the smaller suspended solids contact basins, the equipment represents about two-thirds of the total cost, the ratio being progressively reduced to about half for the largest units.

Summary

The author believes that:

1. Most public water supplies with a hardness of 125 ppm. or more will eventually be softened.

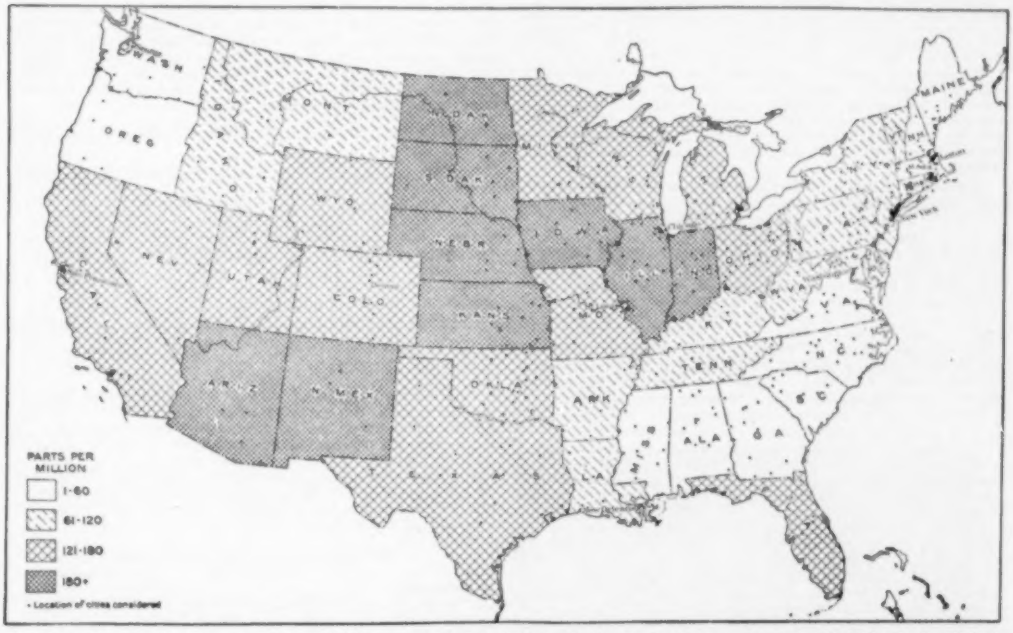
2. Serious consideration should be given to the installation of softening equipment to supplement purification in new filtration projects designed to purify water of a hardness of 125 ppm. or more.

3. The cost of softening hard water is outweighed by the savings which result from the softening. This is particularly true if softening is installed in conjunction with filtration.

4. Softening can be more economically and satisfactorily accomplished in the public water works than by individual softeners servicing each customer.

5. Usually the water customer who is informed of the comparatively small per capita cost of softening water favors softening the entire public supply.

6. Water softening generally effects a saving for the consumer much greater than its added cost, and makes the community a better place in which to live.



Weighted Average Hardness, by States, of Water Furnished in 1932 by Public Supply Systems in Over 600 Cities in the United States (Reprinted from U. S. Geol. Survey Water Supply Paper—658)

Degree of Hardness and Soap Consumption

Grains ($CaCO_3$) per U.S. Gallon	Parts per Million	Pure Soap Consumption (Lbs. per 1000 gals.)	Grains ($CaCO_3$) per U.S. Gallon	Parts per Million	Pure Soap Consumption (Lbs. per 1000 gals.)
1	17.1	1.3	11	188.1	14.8
2	34.2	2.7	12	205.2	16.2
3	51.3	4.0	13	222.3	17.5
4	68.4	5.4	14	239.4	18.9
5	85.5	6.7	15	256.5	20.2
6	102.6	8.1	16	273.6	21.6
7	119.7	9.5	17	290.7	22.9
8	136.8	10.8	18	307.8	24.3
9	153.9	12.1	19	324.9	25.6
10	171.0	13.5	20	342.0	27.0

CONTROL OF ALGAE

By FRANK E. HALE, Ph.D.

Director of Laboratories, Dept. of Water Supply, New York City.

Knowledge of microscopic organisms and their control is one of the more important aspects of water supply practices. Chief amongst agents utilized in algae control is copper sulphate, its application to reservoirs being known as "coppering."

The simplest manner of application is to drag burlap bags, containing about 50 pounds each, through the water by means of rowboats, taking a zigzag course so as to triangulate the surface of the water. Wind, waves, diffusion and gravity admix the streaks of treated water with the remainder. Crude as this method is, it has been found very effective. But it is essential that the chemical be well distributed.

[Recently there has been effectively used by the Los Angeles Water Department a mechanical broadcasting device on the rear of a launch. It distributes pulverized copper-sulphate over the water surface in a manner equivalent to that used in broadcasting fine grass seed. This method reaches shallow shore-line areas most effectively. See Jour. Review, Feby., 1936.]

The reservoir should be partitioned into areas by land sights and the capacity, in million gallons for total depth, calculated for each area so that dosage may be correctly apportioned. In the case of organisms predominating in the upper water, dosage may be calculated on the upper 20-30 feet only. About 3,000 pounds a day may be distributed by a single launch in favorable weather.

Calculation of the volume of a body of water is not difficult. Two formulas should be kept in mind:

One cubic foot contains 7½ gallons.

One gallon of water weighs 8⅓ pounds.

Estimate the area in square feet. Estimate the average depth in feet by soundings. Multiply the two for cubic feet. Multiply cubic feet by 7½ to find gallons and express in million gallons. In the table of treatment which follows one column reads directly in pounds of copper sulphate per million gallons of water to apply for each genus of organisms.

To calculate amount of copper sulphate needed from "Parts per million" column multiply million gallons by 8⅓ to obtain million pounds of water. Multiply this figure by the amount shown in the column headed "Parts per million."

Two formulas are helpful to bear in mind:

1 pound per million gallons = 0.12 part per million.

1.0 part per million = 8⅓ pounds per million gallons.

Copper sulphate may be fed to an aqueduct by continuous dry-feed to destroy organisms feeding from one reservoir to another. The effective dosage is identical with that employed in open reservoirs by the launch method.

Another frequently employed method of continuous feed of copper sulphate is by solution feed. On a small scale a wooden bucket may be suspended in the flowing water so arranged that its depth of submersion may be varied. A small hole in the bottom of the bucket admits the water. The bucket is filled with copper sulphate and a definite amount added once or twice a day and the depth of submersion regulated so as to dissolve the determined quantity each day.

Three to four hundred pounds per day may be fed by a barrel arrangement. By this equipment the chemical is applied as a saturated solution and the application is very uniform. The barrel is kept constantly full of water from a supply controlled by a float valve with glass ball. From the bottom of the barrel, through rubber, glass and copper tubing, the solution is discharged to the water at the most turbulent point. The flow is regulated by a pinch-cock. The barrel sits on a scale so that the weight of chemical delivered may be checked. The water consumed varies with temperature and other conditions from about 1¼ to 2½ gallons per pound of chemical dissolved.

Copper sulphate is very soluble in water. The following table may be useful in feed regulations at various water temperatures:

SOLUBILITY OF COPPER SULPHATE

Temperature: °C.	°F.	Pounds of Copper Sulphate Crystals ($CuSO_4 \cdot 5H_2O$) Per 100 lbs. solution	Per 100 gallons water
0	32	19.5	126.0
10	50	23.1	226.8
20	68	26.9	269.4
25	77	28.9	296.1
30	86	31.3	326.1
40	104	35.3	371.1
50	122	39.1	433.7
60	140	44.6	521.3
80	176	55.5	717.2

Spraying with strong copper sulphate solution is advantageous in some instances, *e.g.*, in shallow bays and on floating masses of certain organisms. For this purpose a spray pump or equipment such as is used with insecticides for trees is available. [An alternate procedure is that used by Los Angeles to mechanically broadcast the pulverized sulphate previously mentioned.—Ed.]

Walls of basins have been sprayed for growths such as Spirogyra, using a 5 per cent solution.

Experience differs with waters of different composition, with temperature, and with amount of organisms present as to the right dosage to apply for each organism. About twice as much chemical is required in winter as in summer. It is a waste of chemical to apply an insufficient amount. If a smaller dosage fails, the entire larger dosage must be applied at one time. The water usually clears within three to four days when the correct quantity has been applied. [See Dosage Tables.] Weeds in general are not killed by copper sulphate. Sometimes fish are killed, but rarely in quantity. The following table indicates the susceptibility of fish to the chemical:

LIMITING SAFE DOSAGE OF COPPER SULPHATE FOR FISH

Fish	Parts per million	Pounds per million gallons
Trout	0.14	1.2
Carp	0.33	2.8
Suckers	0.33	2.8
Catfish	0.40	3.5
Pickerel	0.40	3.5
Gold Fish	0.50	4.2
Perch	0.67	5.5
Sunfish	1.35	11.1
Black Bass	2.00	16.6

Chlorine Treatment

Chlorination is the most valuable adjunct to copper sulphate in control of microscopic organisms. In the first place it helps destroy the odors set free by the copper sulphate treatment. In the second place it destroys many *genera*, in several instances the very ones least affected by copper sulphate.

The use of chlorine in increased dosage has slowly been extended not only to destroy organisms but also the distasteful oils. Experience to date indicates that with soft waters the following effects have been noted:

EFFECTIVE CHLORINE DOSAGES

Organisms Units per cc.	Chlorine ppm. Dose	Residual	Effect— Org. destroyed	Taste destroyed
Synura 1—25	0.2	.05-.10	Yes	Yes
Synura 50—100	0.5-0.7	.20	Yes	Yes
Synura 200	0.7-0.9	.30	Yes	Yes
Uroglena 2,000	0.5	.10	Yes	Yes
Uroglena 6,000	0.5	.10	Yes	No
Dinobryon 500	0.5	.10	Yes	Yes
Asterionella 1,350	0.7	.20	Yes (50%)	No
Aphanizomenon 1,500	0.7-0.8	.20-.25	Yes (50%)	No

Prechlorination with high dosage, 1 ppm. and higher, is employed now quite extensively in conjunction with filtration to destroy or prevent growth of microscopic organisms in sedimentation and reaction basins and lessen their interference with filtration. Longer filter runs are obtained in addition to lightening the bacterial load upon the filters.

Miscellaneous Data. *Cyclotella* has been destroyed by dosage of 1 ppm. *Crenothrix* is another troublesome organism which is readily controlled by chlorine or chloramine in dosage of 0.5 ppm. Chlorine in dosage of 0.33 ppm. has readily controlled or prevented formation of jelly masses or fungus slime in well supplies and in mains and prevented clogging of condensers.

Crustacea, such as *Cyclops* and *Daphnia*, have been controlled on occasions. *Daphnia*, red variety, has been controlled with 1 ppm. chlorine and *Cyclops* with 3 ppm. chlorine.

The following table contains data brought up to date on dosages of copper sulphate and dosages of chlorine required for microscopic organisms, including also odors and tastes produced. It is based on published data and personal experience.

CHEMICALS REQUIRED FOR CONTROL OF DIFFERENT GENERA

Organisms—Odor:	Copper Sulphate[1] Parts per million	Pounds per mil. gals.	Chlorine ppm.
Diatomaceae:			
Asterionella‡	0.12*-0.20*	1.0-1.7	0.5*-1.0*
Aromatic, geranium, fishy			
Cyclotella†‡			1.0
Faintly aromatic			
Diatoma†			
Faintly aromatic			
Fragilaria†	0.25	2.1	
Melosira†‡§	0.20*	1.7	3.0
Meridion			
Aromatic			
Navicula†	0.07	0.6	
Nitzchia§	0.50	4.2	
Synedra†‡	0.36*-0.50*	3.0-4.2	1.0
Earthy			
Stephanodiscus	0.33	2.8	
Tabellaria†	0.12*-0.50*	1.0-4.2	0.5*-1.0
Aromatic, geranium, fishy			
Chlorophyceae:			
Cladophora†	0.50	4.2	
Closterium	0.17	1.4	
Œlastrum†	0.05-0.33	0.4-2.8	
Conferva†	0.25	2.1	
Desmidium	2.00	16.6	
Dictyosphærium†			0.5*-1.0
Grassy, nasturtium, fishy			
Draparnaldia	0.33	2.8	
Eudorina	10.00	83.0	
Faintly fishy			
Entomophora	0.50	4.2	
Gloeocystis			
Offensive			
Hydrodictyon†	0.10	0.8	
Very offensive			
Microspora	0.40	3.3	
Palmella	2.00	16.6	
Pandorina	10.00	83.0	
Faintly fishy			
Protococcus			1.0
Raphidium	1.00	8.3	
Scenedesmus	1.00*	8.3	
Spirogyra†	0.12	1.0	0.7-1.5
Staurastrum	1.50	12.5	
Tetrastrum			1.0
Ulothrix	0.20*	1.7	
Volvox‡	0.25	2.1	0.3*-1.0
Fishy			
Zygnema	0.50	4.2	
Cyanophyceae:			
Anabæna‡	0.12*	1.0	0.5*-1.0
Moldy, grassy, vile			
Aphanizomenon‡	0.12-0.50*	1.0-4.2	0.5*-1.0*
Moldy, grassy, vile			
Clathrocystis	0.12*-0.25*	1.0-2.1	0.5*-1.0
Sweet grassy, vile			
Cœlosphærium‡	0.20*-0.33	1.7-2.8	0.5*-1.0
Sweet grassy			
Cylindrospermum	0.12	1.0	
Grassy			
Microcystis	0.20	1.7	
Oscillaria†	0.20-0.50*	1.7-4.2	1.1
Rivularia			
Moldy, grassy			
Protozoa:			
Bursaria			
Irish moss, salt marsh, fishy			
Ceratium†‡	0.33	2.8	0.3*-1.0
Fishy, vile, (rusty brown color)			
Chlamydomonas	0.50-1.0	4.2-8.3	
Cryptomonas	0.50	4.2	
Candied violets			
Dinobryon‡	0.18*	1.5	0.3*-1.0
Aromatic, violets, fishy			
Endamœba histolytica (cysts)			25.0-100.0
Euglena	0.50	4.2	
Glenodinium	0.50*	4.2	
Fishy			
Mallomonas	0.50	4.2	
Aromatic, violets, fishy			
Peridinium	0.50*-2.00	4.2-16.6	
Fishy, like clam-shells			
Synura‡	0.12*-0.25	1.0-2.1	0.3*-1.0
Cucumber, muskmelon, fishy, bitter taste			
Uroglena‡	0.05*-0.20*	0.4-1.6	0.3*-1.0
Fishy, oily, cod-liver oil taste			
Crustacea:			
Cyclops†‡§			1.0 -3.0
Daphnia†‡§	2.00	16.6	1.0 -3.0
Schizomycetes:			
Beggiatoa†	5.00	41.5	
Very offensive decayed			
Cladothrix	0.20	1.7	
Crenothrix†‡	0.33 -0.5*	2.8-4.2	0.5*
Very offensive decayed, medicinal with chlorine			
Leptothrix†			
Sphaerotilis, natans†	0.40	3.3	
Very offensive decayed			
Spirophyllum†			0.25*
Thiothrix†‡			0.5*-1.0
Fungus:			
Achlya			0.6*
Leptomitus	0.40	3.3	
Saprolegnia†	0.18	1.5	
Miscellaneous:			
Chara†	0.10 -0.50	0.8-4.2	
Nitella flexilis†	0.10 -0.18*	0.8-1.5	
Objectionable			
Potamogeton†	0.30 -0.80	2.5-6.7	
Naias†			1.0*
Blood worm, chironomus†			15.0-50.0
Blood worm, gnats			3.0

The organisms where odors are expressed have been in sufficient quantity at one time or another to cause the characteristic odor.

[1]The quality of water (hard or soft) and temperature has a decided influence on the requisite copper dosage. The harder the water, and the colder, the higher the dosage required. To under-treat is a waste of chemical and further—the whole dosage must be applied at one operation.

*Dosage successful in New York City's supplies.

†These organisms have caused trouble other than odor.

‡These organisms have been affected by chlorine producing characteristic odor and in many cases controlled by dosage ranging from 0.3 to 3 ppm., depending largely on amount of organisms.

§Controlled by excess caustic lime, 5 ppm., in the case of diatoms (48 hrs.).

Los Angeles' Improved Dry-Feed Coppering Machines Used in Algae Control, Surface Applications Have Proved Economical and Effective. All Shallow Areas Are Reached Easily.

PRE-DETERMINING EFFECTIVE DOSAGE OF COPPER SULPHATE IN ALGAE CONTROL

By WILLIAM D. MONIE
Superintendent, Commonwealth Water Co., Summit, N. J.

EVERY engineering problem, regardless of its complexities, is solved by a common sense application of fundamentals. The problem of algae control is no exception and must be solved by the common sense application of fundamentals pertaining to this problem. It is with these fundamentals which we call the A-B-C of algae control that this paper is concerned.

Canoe Brook Reservoir

The supply at the Canoe Brook station of the Commonwealth Water Co. is derived from a combination of artesian well water and a filtered surface supply. The surface water is pumped from a brook during wet seasons and stored in a reservoir approximately 204 acres in area, having an average depth when full of 11 ft., and a maximum capacity of 735 mg. In an average summer this reservoir constitutes a constantly decreasing but fluctuating volume of water, entirely exposed to light, with water temperatures reaching 80 degrees F.

The reservoir of the Commonwealth Water Co. presents three features which make the control of algae especially difficult. With a maximum depth of only 11 ft. when full, it cannot stratify during the growing season, so the nutrients available for algae development are used over and over again, giving maximum crops. Second, light at all times reaches the bottom where dormant stages of algae lying on the mud are quickly stimulated to activity whenever temperature and other factors are favorable. Finally, the reservoir is subject to marked fluctuations in its level. In consequence, the small bays and inlets, which are often the chief breeding grounds for objectionable algae, are frequently drained of their contents. Thus the entire reservoir is seeded again and again.

Algae control in this reservoir was indeed a problem. Records prior to 1939 show that it was not an uncommon occurrence to experience difficulty from luxuriant growths of algae, especially Anabaena and Aphanizomenon. In 1939, despite frequent treatments with copper sulfate from February through October, taste and odor trouble occurred in October because of abundant growths of Anabaena and Aphanizomenon.

A detailed study was then made of the A-B-C's of algae control with copper sulfate with especial consideration of our problem.

The A, B, C, of Algae Control

A—The ability to determine when it is necessary to treat a supply.

B—The ability to determine the correct amount of copper sulfate to apply when treating

C—The ability to apply the treatment so that uniform distribution of the copper sulfate is obtained

When to Treat

In determining when it is necessary to treat a supply, the most important governing point is a recognition of the fact that one must realize copper application is a preventive measure rather than a cure. Therefore, never wait for consumer complaints before treating; treat in ample time to *prevent* the complaints.

The best method of determining when it is necessary to treat a supply is by microscopic examination. When an organism is growing to such a point that it may cause trouble, daily microscopic examination and count should be made of samples taken directly from the reservoir. From the count and speed or rate of growth, it can be determined when the supply should be treated.

There are two points in the above paragraph which should be stressed: 1—Samples should be collected directly from the reservoir for microscopic examination. If samples are collected from a main, or after passage from a pump, delicate organisms are broken up and some become unrecognizable. 2—In the growing season daily microscopic examinations must be made. It is surprising how rapidly organisms increase in number when growing conditions are ideal. It is not uncommon to have an organism more than triple its numbers within one to two days.

From experience at the Canoe Brook reservoir certain upper limits of safety, beyond which treatment was necessary, were determined for each organism. These are—

Organism	Count*
Asterionella	1,000-1,200
Mallomonas	800-1,000
Anabaena	600- 800
Aphanizomenon	300- 600

*Total number of organisms in ten fields at a magnification of 100x.

It was decided to apply copper sulfate only when an organism reached these limits, as it had proven uneconomical to attempt control when the organism is just starting to increase.

Keep an Eye on the Thermometer

The growth of different types of organisms can be anticipated by the temperature of the water, especially surface temperatures. According to Nelson,[2] "approximately twenty years ago Dr. Setchell, botanist of the University of California, pointed out that there are definite ranges of temperature within which various flowering plants begin to grow and higher ranges at which they will flower. These critical temperatures were found to lie close to 5°, 10°, 15°, 20° and 25° C. (41°, 50°, 59°, 68° and 77° F.). His studies showed that as the temperature passed the critical point certain species were suddenly stimulated to activity. Hydrobiologists working with algae and protozoa are finding similar critical temperatures. Owing to the more gradual temperature changes which occur in the water, these ranges are more easily recognized and delimited than is the case with land plants."

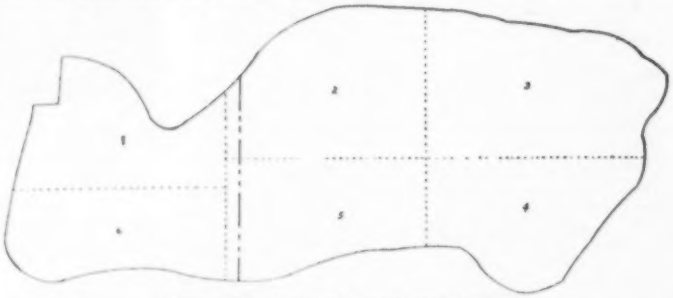
It has been our experience that different species of algae have started to grow at these temperatures. Therefore, as the temperature of the water reaches these critical temperatures get out your microscope and keep a close watch on the algae growth.

How Much Copper to Apply

It was with this factor—how much copper sulfate to use in treating—that we experienced the most difficulty. Many times what appeared to be an effective treatment three days after the application of the salt found an aftergrowth of the same organism within a week of treating that reached greater numbers than were present before the sulfate was applied.

Many Factors Govern Dosages

In regard to the question of the amount of copper sulfate to use in treating a supply, Hale[1] states: "Experience differs with waters of different composition, with temperature and with the amount of organism present as to the right dosage to apply for each organism. It is a waste of chemical to apply an insufficient amount. If a smaller dosage fails, the entire larger dosage must be applied at one time."



Diagrammatic Sketch of Canoe Brook Reservoir

The dotted lines show how reservoir is sectioned for purposes of sampling water and applying copper sulfate in correct proportion to water depth and algae concentrations. During algae growing season each section is sampled daily and given microscopic examination—believing that the old adage about an ounce of prevention being worth pounds of cure holds nowhere more pronouncedly than in algae control.

Therefore, it is *a waste of chemical to apply an insufficient amount*, just as it is a waste to apply an excess amount.

We used the table based on data by Moore and Kellerman, Whipple and others[1] as a starting point, and attempted to apply it to conditions existing at our plant. However, one of the organisms with which we experienced considerable difficulty was Aphanizomenon. The table gave a range of 1.0-4.2 pounds per mg. for the control of this organism. Furthermore, past experience showed that treatments of 1, 2, 3 and 4 pounds per mg. had all been effective for the control of Aphanizomenon at one time or another. We realized that if we treated for Aphanizomenon with 1 pound of copper sulfate per mg. when 4.2 pounds per mg. might be needed, the 1 pound per mg. treatment would be wasted, since the 4.2 pounds per mg. must be applied at one time to be effective. Likewise, if the 4.2 pounds per mg. was used and 1 pound per mg. would have done the work, then 3.2 pounds per mg. would be wasted.

With so many factors influencing the amount of copper sulfate to use in treating a supply, algae control would certainly be much more scientific if we had a test that would allow us to say definitely how much copper sulfate it was necessary to use to satisfy all conditions. In September of 1940 the author devised a simple, practical laboratory test to determine the amount of copper sulfate necessary to use in treating a supply of water regardless of its temperature and composition and, within certain limitations, regardless of the type and amount of organism present.

The "D. M." Test

It was found that the addition of certain amounts of copper sulfate to water containing algae resulted in an increase in the alkalinity. The amount of copper sulfate needed to bring about this increase in alkalinity was the correct amount to use in treating. After much experimentation the following test was developed.

The equipment and chemicals necessary for the test are as follows:

a. Six 50 ml. nessler tubes.
b. A copper sulfate solution of a strength that 2 ml. added to a liter of water equals a copper sulfate treatment of 1 pound per mg.
c. Phenolphthalein indicator.
d. 0.01136 N Na OH

To make the copper sulfate solution mentioned in b, dissolve 0.6 gram of the copper sulfate you use in 1 liter of distilled water. Dilute 100 ml. of this solution to 1 liter with distilled water. Two ml. of this final solution per liter of sample equals one pound of copper sulphate per mg., or 0.1 ml. per 50 ml. of sample equals one pound of copper sulfate per mg.

Tube Inversion Rack Used in "D.M." Test. (Honesdale, Pa., Water Co.)

Test Procedure

In each of six 50 ml. nessler tubes A, B, C, D, E and F, 50 ml. samples of the water to be treated are placed. To tube A, add 0.1 ml. of the copper sulphate solution (b) to equal a treatment of 1 pound per mg.; to tube B, 0.2 ml. of solution (b) is added to equal a treatment of 2 pounds per mg.; to tube C, 0.3 ml. of solution (b) is added to equal a treatment of 3 pounds per mg.; to tube D, 0.4 ml. of solution (b) is added to equal a treatment of 4 pounds per mg.; to tube E, 0.5 ml. of solution (b) is added to equal a treatment of 5 pounds per mg. To tube F, no copper sulfate is added. These samples are then mixed by corking and inverting approximately thirty times simultaneously.

To the nessler tube F (the blank sample) phenolphthalein indicator is added. If there is a negative amount of free carbon dioxide present, enough indicator is added until there is a faint but distinct pink color. Then the same amount of phenolphthalein is added to each of the other samples. The samples are compared and the tube with the deepest color is the tube containing the sample to which has been added the correct amount of copper sulfate to use in treating.

Influence of Carbon Dioxide

If there is free carbon dioxide present (and there usually is), three drops of phenolphthalein is added to each of the six samples in the nessler tubes after they have been mixed with the various amounts of solution (b) as described above. Then 0.01136N sodium hydroxide is added to the nessler tube F (the blank sample) until there is a faint but distinct pink color. The same amount of the sodium hydroxide is then added to the other five samples and the tubes are compared for color. The deepest color will be found to be in the tube containing the sample to which the most effective and economical amount of copper sulfate to use in treating has been added.

This test is practically the same as a free carbon dioxide titration. However, in the algae test it is simpler to have both the phenolphthalein and the sodium hydroxide in dropper bottles, as the equal amounts can be easily added to the sample tubes by counting the drops. 0.01136N sodium hydroxide is used simply because finer control can be maintained on the color. In waters with considerable carbon dioxide, 0.02272N can be used just as effectively.

It is important to note that the tube with the deepest color is always darker than the blank sample. Therefore, at the correct dosage of copper sulfate the water is more alkaline than it was prior to the addition of the salt. This result is clearly shown in the test irrespective of the fact that phenolphthalein is not a sensitive indicator. The puzzling factor of the entire test is the fact that at a certain concentration of copper sulfate dosage the alkalinity is increased, and then with an excess of copper sulfate the alkalinity decreases to approximately the same point as it was in the blank sample. Therefore the color in the tubes rises gradually with the dosage increase and after reaching a maximum the overdosage causes a lessening color development.

When the "D. M." test was first developed the author used a mixing machine with liter samples instead of the nessler tubes. However, the reaction in the test is so fast that the results can be obtained quicker with equal accuracy using the nessler tubes.

The accompanying picture illustrates a simple gadget made by the Honesdale Consolidated Water Co., Honesdale, Pa., for use in inverting the nessler tubes for mixing purposes. Although such an instrument is handy, accurate results are obtained when the mixing is done by hand.

If more than one type of organism is present in sufficient numbers it is possible to get two or more treating points by the "D. M." test. For example, Anabaena and Aphanizomenon were present at the same time in the water at Canoe Brook reservoir. The "D.M." test showed two distinct treating points, two pounds per mg. and four pounds per mg. To use two pounds per mg. would have been a mistake as only the Anabaena would have been destroyed, which would leave conditions perfect for the rapid increase of the Aphanizomenon.

Proper Method of Copper Application

Proper distribution of the copper salt through the reservoir water is important to successful algae control. Knowledge of the first two steps for algae control—when

Method of Coppering
Rowboat with outboard motor and copper sulfate applied from burlap bags, with quantity in the bags determining the dosage.

to treat, and how much salt to use in treating—would be of no value without proper application of the chemical. For example, if a four-pound per mg. treatment of copper sulfate is necessary, then the salt must be applied so that the water in all parts of the reservoir has received approximately a four-pound per mg. treatment. The deeper parts of the reservoir must receive in proportion more salt than the shallow parts. If this is not done, some portions of the water will be undertreated and the algae not killed in these parts will remain to re-seed the reservoir.

Here, again, a detailed study of conditions of each reservoir must be made and the method of application decided upon after careful deliberation. In the majority of lakes the best method of application is by dissolving the copper sulfate from burlap bags or perforated boxes attached to a boat. However, in some lakes and for certain types of algae some other method of application such as spraying either a solution of copper sulfate or broadcasting the pulverized dry salt may be more practical.

Knowledge of Reservoir Topography Important

In order to obtain proper uniform distribution of the chemical a knowledge of the reservoir bottom topography is an important consideration. If you do not have a contour map of the reservoir bottom, make one. The points for preparing such a map are easily obtained by soundings from a boat or from the ice in northern regions.

When the reservoir bottom topography is known it is a simple matter to section the reservoir into areas of approximately uniform depth. With this knowledge it is possible to apportion the salt in treating so that equitable application can be planned and made. In deep reservoirs usually only the top twenty feet need be considered in treating.

Method of Applying Chemical

At the Canoe Brook reservoir the treating is done by means of a boat propelled by an outboard motor. The chemical is placed in two burlap bags, one on each side of the boat, suspended from frames so that additional salt can be added to the bags to keep the amount of salt exposed to the water uniform. The strength of the treatments is regulated by the level of sulfate carried in the bags.

The conventional strip method is used in treating. After experimenting, the strips now used are approximately forty feet wide. This width of strip allows the reservoir to be treated in an eight-hour day with one boat. The same width of strips is adhered to regardless of the amount of salt per treatment, the amount of salt going into solution depending upon the amount exposed to the water.

In a case where a reservoir is so large that strips over 100 feet are necessary, more than one boat should be used in treating.

Results

The following table illustrates the results obtained over a seven-year period from 1939 through 1945 at the Canoe Brook reservoir. In five of these years the copper dosage was determined through the use of the "D.M." test.

Year	Treatments	Lbs. $CuSO_4$
1939	27	33,750
1940	7	11,250
1941	8	14,350
1942	3	6,200
1943	2	3,700
1944	3	5,200
1945	3	5,200

As shown by this table gratifying results were obtained by practical application of the fundamental A-B-C of algae control. From the last treatment in 1940 the "D.M." test was used in determining the amount of copper sulfate to use in treating.

There has not been a treatment where the amount of salt used was determined by the "D.M." test that was *not* successful. Additional success since 1941 is believed to be due to changes made in applying the fundamentals of when to treat and how to apply the salt.

One interesting observation during systematic use of the "D.M." test is that the amount of salt necessary to destroy certain organisms increases as the number of the organisms present increases until a certain point is reached and then the amount of salt required decreases as the organism continues to increase in numbers. This circumstance is unexplained.

References

(1) Hale, Frank E., "The Use of Copper Sulphate in Control of Microscopic Organisms." Phelps-Dodge Refining Co., New York. (Revised 1935.)

(2) Monie and Nelson, "Algae Control." *Jour. A.W.W.A.*, April, 1941.

Pounds of Chemicals per Hour for Various Pumpages and Doses

PUMPAGE		DOSE - POUNDS PER MILLION GALLONS															
MILLION GALLONS IN HRS.	THOUSAND GALLONS PER HOUR	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
		DOSE - GRAINS PER GALLON															
		.07	.14	.21	.28	.35	.42	.49	.56	.63	.70	.77	.84	.91	.98	1.05	1.12
1.0	41.7	.417	.833	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00	5.42	5.83	6.25	6.67
1.5	62.5	.625	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50	8.13	8.75	9.38	10.0
2.0	83.3	.833	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.0	10.8	11.7	12.5	13.3
2.5	104	1.04	2.08	3.13	4.17	5.21	6.25	7.29	8.33	9.38	10.4	11.5	12.5	13.5	14.6	15.6	16.7
3.0	125*	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.0	11.3	12.5	13.8	15.0	16.3	17.5	18.8	20.0
3.5	146	1.46	2.92	4.38	5.83	7.29	8.75	10.2	11.7	13.1	14.6	16.0	17.5	19.0	20.4	21.9	23.3
4.0	167	1.67	3.33	5.00	6.67	8.33	10.0	11.7	13.3	15.0	16.7	18.3	20.0	21.7	23.3	25.0	26.7
4.5	187	1.88	3.75	5.63	7.50	9.38	11.3	13.1	15.0	16.9	18.8	20.6	22.5	24.4	26.3	28.1	30.0
5.0	208	2.08	4.17	6.25	8.33	10.4	12.5	14.6	16.7	18.8	20.8	22.9	25.0	27.1	29.2	31.3	33.3
5.5	229	2.29	4.58	6.88	9.17	11.5	13.8	16.0	18.3	20.6	22.9	25.2	27.5	29.8	32.1	34.4	36.7
6.0	250*	2.50	5.00	7.50	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0	32.5	35.0	37.5	40.0
6.5	271	2.71	5.42	8.13	10.8	13.5	16.3	19.0	21.7	24.4	27.1	29.8	32.5	35.2	37.9	40.6	43.3
7.0	292	2.92	5.83	8.75	11.7	14.6	17.5	20.4	23.3	26.3	29.2	32.1	35.0	37.9	40.8	43.8	46.7
7.5	312	3.13	6.25	9.38	12.5	15.6	18.8	21.9	25.0	28.1	31.3	34.4	37.5	40.6	43.8	46.9	50.0
8.0	333	3.33	6.88	10.0	13.3	16.7	20.0	23.3	26.7	30.0	33.3	36.7	40.0	43.3	46.7	50.0	53.3
8.5	354	3.54	7.08	10.6	14.2	17.7	21.3	24.8	28.3	31.9	35.4	39.0	42.5	46.0	49.6	53.1	56.7
9.0	375*	3.75	7.50	11.3	15.0	18.8	22.5	26.3	30.0	33.8	37.5	41.3	45.0	48.8	52.5	56.3	60.0
9.5	396	3.96	7.92	11.9	15.8	19.8	23.8	27.7	31.7	35.6	39.6	43.5	47.5	51.5	55.4	59.4	63.3
10.0	417	4.17	8.33	12.5	16.7	20.8	25.0	29.2	33.3	37.5	41.7	45.8	50.0	54.2	58.3	62.5	66.7
10.5	437	4.38	8.75	13.1	17.5	21.9	26.3	30.6	35.0	39.4	43.8	48.1	52.5	56.9	61.3	65.6	70.0
11.0	458	4.58	9.17	13.8	18.3	22.9	27.5	32.1	36.7	41.3	45.8	50.4	55.0	59.6	64.2	68.8	73.3
11.5	479	4.79	9.58	14.4	19.2	24.0	28.8	33.5	38.3	43.1	47.9	52.7	57.5	62.3	67.1	71.9	76.7
12.0	500*	5.00	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
12.5	521	5.21	10.4	15.6	20.8	26.0	31.3	36.5	41.7	46.9	52.1	57.3	62.5	67.7	72.9	78.1	83.3
13.0	542	5.42	10.8	16.3	21.7	27.1	32.5	37.9	43.3	48.8	54.2	59.6	65.0	70.4	75.8	81.3	86.7
13.5	562	5.63	11.9	16.9	22.5	28.1	33.8	39.4	45.0	50.6	56.3	61.9	67.5	73.1	78.8	84.4	90.0
14.0	583	5.83	11.7	17.5	23.3	29.2	35.0	40.8	46.7	52.5	58.3	64.2	70.0	75.8	81.7	87.5	93.3
14.5	604	6.04	12.1	18.1	24.2	30.2	36.3	42.3	48.3	54.4	60.4	66.5	72.5	78.5	84.6	90.6	96.7
15.0	625*	6.25	12.5	18.8	25.0	31.3	37.5	43.8	50.0	56.3	62.5	68.8	75.0	81.3	87.5	93.8	100.0

* Bread Values

1 grain per gallon = 143 pounds per million gallons = 5.95 lbs. per hour for each million gallons
0.70 " " " = 100 " " " " = 4.17 " " " " " "

Example: What weight of Chemical must be fed each hour to give a 70 lb dose for a pumpage of 8.0 M.G.D.
Opposite 8.0 M.G.D. and under 70 find 33.3, which is the correct weight.

ACTIVATED ALUM SALES CORPORATION

316 WYNDHURST AVENUE • BALTIMORE 10, MD.

Activated Alum for Water Treatment

Activated Alum is a non-hygroscopic mixture of filter grade alum containing very finely pulverized particles of clay in a thoroughly dispersed form. The purpose and advantage of the suspended clay is to provide the nuclei for floc formation, and to supply the weight necessary to attain better settling characteristics after the floc is formed.

APPLICATIONS

Activated Alum is generally accepted as the best coagulant for removing color and suspended matter from highly colored waters, and waters which vary through a considerable range of turbidity.

HANDLING

For convenience in handling, the Activated Alum Corporation has popularized the use of 100 lb. disposable paper bags. These bags, in addition to being easier to handle than the 200 lb. cloth bags, eliminate the nuisance caused by loose fibres of burlap becoming entangled in the mechanical parts of the feeder.

STORAGE

Due to the non-hygroscopic qualities of Activated Alum, users have found that this material can be stored for relatively long periods of time without loss due to caking.

SHIPPING

Water of crystallization in Activated Alum is held to approximately 25%, as compared to an average of 45% in ordinary alum. Paying by the pound for shipping unnecessary quantities of water is thus eliminated.

FEEDING

The non-hygroscopic properties of Activated Alum are of great advantage in overcoming the difficulties caused by "arching" in the feeder hoppers under damp atmospheric conditions.

DISSOLVING

The structure of the particles of Activated Alum is highly porous. This porosity is secured in the process of manufacture and is of assistance in speeding up the dissolving action in the mixing chamber of chemical feeders. Dissolving time is actually only about half that required for crystalline alum.

CHEMICAL ANALYSIS

Activated Alum has the following typical analysis:

Alumina (Al_2O_3)	17.9%
Insolubles	9.0%
Iron (Fe_2O_3)	0.3%
Acidity	0.0%
Basicity	0.2%

the alumina (Al_2O_3) in alum is the measure of its strength. Note this is nearly 18% in Activated Alum.

SERVICE

Activated Alum Corporation, unlike all other concerns supplying alum, specializes exclusively in its production. This fact is chiefly responsible for the unique service we are able to render . . . a service by which it is often possible to furnish the required quantity of Activated Alum to water works operators within hours of the receipt of emergency calls.

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AQUA NUCHAR ACTIVATED CARBON

Aqua Nuchar is a quality of activated carbon specifically produced for water purification. Its characteristic is a high adsorptive power for those foreign molecules in water which give rise to objectionable odors. Aqua Nuchar offers the quickest, lowest-cost way to eliminate odors and prevent their recurrence. It is estimated that the year 'round use of Aqua Nuchar Activated Carbon costs on an average less than two cents per capita per year.

With the increase in use of activated carbon in water treatment, competitive carbons and competitive treatments entered the field. Thus it became necessary to develop tests and suitable specifications whereby municipalities would be able to select the activated carbon most suitable for their individual needs.

Development of the Theshold Odor Test supplied the means of measuring odor intensities in water and by means of this test it is possible to determine that quality of carbon which will be most effective for removing odors from the individual supply. Municipal officials are invited to write us for full information regarding this test.

Members of our Research Staff have carried on evaluation tests, comparing Aqua Nuchar with competitive materials for ability to remove odors.

Odors in water are frequently erroneously characterized as tastes. Psychologists recognize four taste sensations; salt, sweet, sour and bitter. Perhaps the greatest cause of odor in water supplies is due to Algae. Odor is occasionally caused by trade wastes, resulting in very severe odor epidemic. Aqua Nuchar removes these odorous compounds in water, thus enabling delivery of a palatable water to the consumer at all times.

Even where there has been no consumer complaint, many plants apply small dosages of Aqua Nuchar in order to prevent a sudden taste or odor condition from getting out of hand. Thus, when tastes and odors develop in a raw water supply, it is only necessary to apply somewhat increased dosages of Aqua Nuchar to control the condition.

AQUA NUCHAR HAS THESE SPECIAL QUALITIES: It disperses more quickly throughout the entire body of water and remajns in suspension a longer period of time. Thus the carbon particles have a greater opportunity to contact taste and odor bodies in the water in order to accomplish their REMOVAL BY ADSORPTION.

It is common practice in the design of new plants to provide for activated carbon treatment of the water. Application of Aqua Nuchar Activated Carbon is advisable not only in all water supplies where tastes and odors may be present, but also in water where tastes and odors become apparent after chlorination. It is a wise precaution under all circumstances.

During floods and high water, odorous compounds may be flushed down to your water intake. Therefore at such times Theshold Odor Tests should be run regularly and you should be prepared with an adequate supply of Aqua Nuchar.

The manufacturers of Aqua Nuchar Activated Carbon offer the services of Technical Field Men to study your methods and recommend the proper place to add activated carbon. They have studied the taste and odor problems of hundreds of plants with surface water supplies and can quickly find the point at which activated carbon should be added to give optimum results.

Warehouse and factory stocks are maintained at strategic points throughout the country so that rush deliveries can usually be made within twenty-four hours or less by local express.

ACTIVATED NUCHAR CARBON

Snow Top Precipitated Calcium Carbonate—USP • Ligro Crude Tall Oil • Indusoil Distilled Tall Oil
Talloco Tall Oil Pitch • Tallex Abietic Acid • Indulin (Lignin)

FACTORS INFLUENCING THE EFFICIENCY OF ACTIVATED CARBON*

By D. COLEBAUGH, J. FILICKY and A. HYNDSHAW
West Virginia Pulp & Paper Co., New York

POWDERED activated carbon was first used in 1930 to control disagreeable tastes and odors in public water supplies by George Spalding of the Hackensack Water Co. at New Milford, N.J. Since then, its use has steadily increased until approximately 1,300 plants now employ it to control tastes and odors.

The process by which activated carbon removes the taste and odor bodies is known as adsorption. Our knowledge of the actual nature of adsorption is limited, although there has been evidence that the process may be physical, chemical, electrical or combination of all three. Practical operators are not so much concerned with the nature of adsorption, of course, as with the benefits derived from its action. Of primary interest to water works operators, therefore, is the action of activated carbon in eliminating tastes and odors in water.

Numerous factors affect the efficiency of carbon in adsorption. Some of these are not within the control of the water works operator; others, however, can be controlled. For example, the action of carbon is influenced by the duration of the contact period and the nature of the other chemical treatment. The latter influence is of particular interest to the water works operator because the chemicals used for disinfection or softening will often produce changes in the taste- and odor-bearing substance. Methods of solving this type of problem can best be explained by describing actual experiences.

Influence of pH

The efficiency of adsorption by activated carbon is influenced by the pH value of the water. In one midwestern city, decreased adsorption was noted at a high pH. During a taste and odor survey conducted at this plant, unsuccessful attempts were made to prepare odor-free water by passing tap water through a granular carbon filter. Only by reducing the pH of the tap water from 10.5 to 7.5 was the preparation of odor-free water by this method possible.

Special attention is usually required when carbon is applied at plants which use lime for softening or pH adjustment. Frequently a change in the order of adding chemicals is advantageous. At one plant in Minnesota, 75 lb. per mil.gal. (9 ppm.) of activated carbon removed only 10 per cent of the odor when the pH was 10.6, whereas the addition of carbon before the lime resulted in a 70 per cent reduction.

Certain compounds, such as phenols, are less adsorbable at pH values above 8. An explanation for the decreased adsorption may lie in the fact that alkali converts the phenol to phenolate, the degree of conversion being proportional to the increase in pH. Because the salt of phenol is difficult to adsorb, decreased adsorption usually follows an increase in the formation of sodium phenolate.

A few compounds, such as aniline or pyridine, are much more readily adsorbed at high than at low pH values, but these compounds are rarely found in water supplies.

It should be mentioned, however, that in numerous water supplies, pH has less influence than in the situations described above.

Contact Time

Adsorption normally occurs as soon as carbon establishes contact with the taste and odor bodies. In a water plant where carbon dosage is relatively small, longer contact periods are desirable. Thus, in one midwestern city, satisfactory adsorption of taste and odor bodies by carbon was obtained by increasing the contact time from 15 to 30 minutes. At this plant, also, a decreased efficiency of carbon, caused by high pH of the water (10.5), was overcome by increasing the time of contact.

Chlorine

It is an almost universal practice to employ chlorine in some form or other for disinfection of raw water. Many plants, however, also use chlorine to control taste and odor, with varying degrees of success. Some plants have obtained decided improvement with the use of chlorine, whereas others have not. A number of plants using superchlorination, free residual chlorination, or marginal chlorination for taste and odor control employ supplementary treatment with carbon to produce a water acceptable to the public. In 1946, during an outbreak of *Asterionella* in an Ohio water plant, free residual chlorination reduced odor 40 per cent, but changed the characteristic taste of the water and made it unpalatable. It was necessary to supplement the treatment with carbon to reduce the concentration of odors in the water to a satisfactory level.

On occasion it has been advisable to change from free residual to marginal chlorination to prevent the formation of chlorinated compounds which were more unpleasant than those in the raw water. Thus, in one city in Illinois in 1948, a change from free residual to marginal chlorination was effective in producing a final product which was acceptable to the public. One city in Louisiana found that free residual chlorination changed the characteristic grassy odor of the water to a woody odor without changing its intensity.

At times free residual chlorination has intensified odors. Threshold odor tests conducted in a large midwestern city in 1947 revealed that increased concentrations of odors were caused by the formation of chlorinated compounds. Further studies indicated that each pound of free chlorine residual per million gallons (0.12 ppm.) increased the threshold odor value 2 units above that of unchlorinated water.

Other effects of carbon in combination with chemicals used for disinfecting water require consideration. For example, chlorine and carbon have an affinity for each other; the chlorine absorbed by the carbon is converted to a chloride by catalysis. It has been reported that carbon can adsorb 10 per cent of its weight of chlorine and still remain effective for adsorbing taste and odors. The decreased efficiency of carbon which would result from applying the two chemicals together is insignificant, but the oxidation potential of the chlorine would be destroyed. For this reason the point of application must be carefully chosen to prevent any possible interferences between the two chemicals.

It is frequently desirable for the water works operator to apply carbon after free residual chlorination, thus enabling the chlorine to effect some odor improvement and to reduce the amount of carbon required to produce a palatable water. This method was applied successfully in one city in Ohio in 1947, during an algae outbreak. Free residual chlorination followed by carbon was found to be more effective in removing taste and odors than either treatment used separately.

By contrast, a city in Texas in 1948 found chlorination detrimental to the action of carbon which was added later. The characteristic odor of the raw water was changed to an odor more difficult to adsorb than the original. Better results at this plant were obtained by adding carbon before chlorination.

Chloramines

The addition of ammonia to water, prior to treatment with chlorine, often prevents the formation of malodorous compounds resulting from the action of the chlorine on taste and odor compounds.

Three types of chloramines may be present in water—mono- and di-chloramine and nitrogen trichloride. Of the three, monochloramine is considered least adsorbable by carbon.

Coagulation

Because of the proximity of the standby feed equipment and pipelines, the mixing basin is generally considered the most convenient point for applying carbon. Several advantages may be realized at this point of application:

1. The carbon can act as a nucleus upon which floc particles may form.
2. Sludge is stabilized.
3. Caking of sludge can be prevented, permitting the sludge to be hosed to the sewer.

In a city in Massachusetts in 1949, floc formation was found to interfere with the action of the carbon. The floc was so heavy that the carbon was immediately taken up and the adsorption of the taste and odor bodies was greatly reduced. Adjusting the floc formation to allow a longer period of contact resulted in a 90 per cent increase of the amount of odor removed.

Filters

Much has been said about the merits of carbon application to the tops of the filters. There are two primary objections, however, to this point of application. The first is that the filter runs are shortened, although filters kept in good condition are not appreciably affected. One large city in the midwest has applied as much as 350 lb. per mil.gal. (42 ppm.) directly upon the filters without having carbon pass through the filters or shortening the filter runs. Application of carbon to the tops of the filters actually accelerated the filtering rate.

The other objection is that carbon may pass through the filters. If carbon does pass

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through, it can be readily detected by its characteristic black color. When this happens, there is a good chance that other substances, not so easily detectable, are also passing through; thus carbon frequently acts as an indicator of other impurities. To correct such conditions, it is necessary to check other operations in the plant. In one city the trouble was found to be caused by a weir which was breaking up the floc; as a result, alum as well as carbon was passing through the filter. At a Minnesota plant, the coal particles used for filtering were found to be too large for proper filtration. Inspection of the filter effluent revealed the presence of alum floc as well as carbon.

Chlorine Dioxide

Quite recently chlorine dioxide was applied to the waters of clear wells for the elimination of medicinal tastes and odors. In one city in New York, where chlorine dioxide was tried for the disinfection of the water, it was applied in the settling basin. If chlorine dioxide is to be used for disinfection, selection of the point of carbon application will probably be influenced as it is with chlorine. The use of chlorine dioxide as a taste and odor control agent may be best illustrated by citing several plant studies.

Medicinal tastes and odors are sometimes present in the raw water of one plant in Kentucky. Plant studies conducted in 1948 indicated that chlorine dioxide used on a cost basis was more efficient than activated carbon in removing this taste and odor. With algae tastes and odors, however, the chlorine dioxide had little or no effect, and for these, activated carbon had to be relied on to produce a palatable water.

Tests made in 1949 at a plant in Wisconsin indicated that chlorine dioxide applied to the clear well did not effect any reduction in the algae tastes and odors, but acted rather as a specific for phenol contamination, which is encountered during the winter months.

Similar studies at a plant in Minnesota indicated that supplementary chlorine dioxide (0.6 to 1.2 ppm. sodium chlorite) applied to the clear well did not extend the odor reduction beyond the point already reached with activated carbon. Applying the chlorine dioxide to the raw water only decreased the raw water odor (swampy type odor) from the threshold odor 14 to an average threshold odor of 12. Generally, the threshold odor number of the tap water should be 5 or less for the water to be considered palatable.

Handling Activated Carbon

Activated carbons used for water purification are delivered in a very finely divided state, the greater part passing a 325-mesh screen. This extreme fineness, combined with the apparently low density of the carbon, results in dusting and wetting characteristics which can be quite troublesome if preventive measures are not taken.

Although some dusting usually occurs during unloading of the carbon packages, the greatest amount is encountered when the carbon is emptied from the bag into the feeding hopper. This may be minimized by suitable handling procedures, and the scattering of dust may be reduced by installing dust collectors. These usually operate by creating a partial vacuum at the hopper door which prevents the escape of carbon particles.

When bag type dust collectors are used, it is essential that the bags be cleaned frequently to maintain maximum efficiency for the dust collecting system. Portable dust collectors equipped with suction hose are now available, and can be used to pick up carbon that has been accidentally spilled or remove carbon dust that has accumulated over a period of time. A barrel or chute to a closed bin should be provided for disposal of the empty bags.

New methods of handling and feeding activated carbon have been investigated and results show that carbon dusting can be practically eliminated by receiving carbon in bulk (closed hopper cars or trailer truck) and using wet storage. Even if it is not feasible to receive bulk shipments of carbon, wet storage has advantages over dry storage, particularly in eliminating dust. When a shipment of carbon is received, the bags may be emptied directly into the wet storage tanks. Wet storage not only eliminates dusting during carbon application, but also eliminates the labor cost of moving carbon both into and out of storage.

The wet storage tank should be equipped with an agitator to maintain a uniform suspension at all times. Proportioning devices such as a Moyno pump, rotometers and weirs may be used for controlling the amount of carbon required for taste and odor conditions.

"Moisturized" carbon may be used where wet storage is not possible. This is carbon of standard quality, differing only in its water content. The amount of water added to minimize dusting is equal in weight to 20 per cent of the carbon.

PACKING POINTERS

The following suggestions and warnings, based on the many years of practical experience of a prominent eastern packing manufacturer, will be found valuable in the installation of packings. To follow them may mean freedom from trouble that would occur when even the best packing is improperly installed.

1. NEVER fail to make clear to the manufacturer what the packing is to pack. In other words, with what will the packing make contact?
2. NEVER guess at a size, diameter, width, or height, when ordering packing. Many failures result from small errors in dimensions.
3. NEVER allow too little or too much clearance between follower plate and inside cup wall, or any metal parts behind any upright leather wall. Clearances of 1/16" to 3/32" on each side, depending on size of packing, is recommended.
4. NEVER doctor packing lips with a pocket knife or file, or batter lip in installing. A rounded lip destroys the seal. Packings can be softened by soaking in warm water if necessary.
5. NEVER apply cup packings with flange too high for clearance at the head of the cylinder. Keep systems clean, so sediment will not collect in cylinders and wear the packing.
6. NEVER apply cup packings to end of badly worn plungers; pressure will force the packing down into clearance between plunger and cylinder. Leather washers cut from old cup packings can be made to reline such equipment to proper dimensions.
7. NEVER apply "U" packings where plungers are worn without reinforcing under the heel with leather cushion rings.
8. NEVER look for long service on scored plungers or in scored cylinders; resurface or reline such equipment to proper dimensions.
9. NEVER allow water to corrode cylinder walls, plungers, stems or rods. Use an anti-rust agent that will prevent this and will act as a lubricant.
10. NEVER squeeze hemp or fabric filled "U" packings in glands where such packings are to replace solid section compression packings; set gland up to point where "U" packings are free to function properly.

FOR PRECISE pH Control and WATER TESTS

there is nothing like

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Since their introduction in 1926, Hellige Non-Fading Glass Color Standards have proved their unvarying reliability in diversified scientific fields. Their permanence provides greater economy and insures against the variation with resultant error encountered in the use of solution standards. Hellige standards have demonstrated their dependability under the most severe climatic conditions and are specified exclusively by the U. S. Army and Navy for protection against contaminated water. As reliable colorimetric controls, the record of service of our Non-Fading Glass Color Standards cannot be duplicated.

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The Hellige "Turbidimeter without Standards" is a highly accurate instrument of modern design. Our application of the Tyndall effect to the liquid under test eliminates the need of standard suspensions and assures reproducible results regardless of line voltage fluctuation. Precise determinations are performed in the ranges of zero to 150 p.p.m. SiO_2 and zero to 100 p.p.m. SO_4. Higher values are determined by diluting the test sample. Foolproof and versatile, the Hellige Turbidimeter also is employed for measurements of colloids and suspended matter in general. Convenient, trouble-free operation assures accurate readings even to those without special training in this field.

Hellige "Chromatron" Photoelectric Colorimeter and Turbidimeter for analyses of water, sewage, and industrial wastes using A.P.H.A. and A.W.W.A. standard methods. Features complete portability; selective color filters covering entire visible spectrum; square precision absorption tubes; hermetically sealed photocell; extremely sensitive meter; automatically focused bulb and corrosion resistant stainless steel working parts. Unsurpassed simplicity and ease of operation both in the laboratory and in the field.

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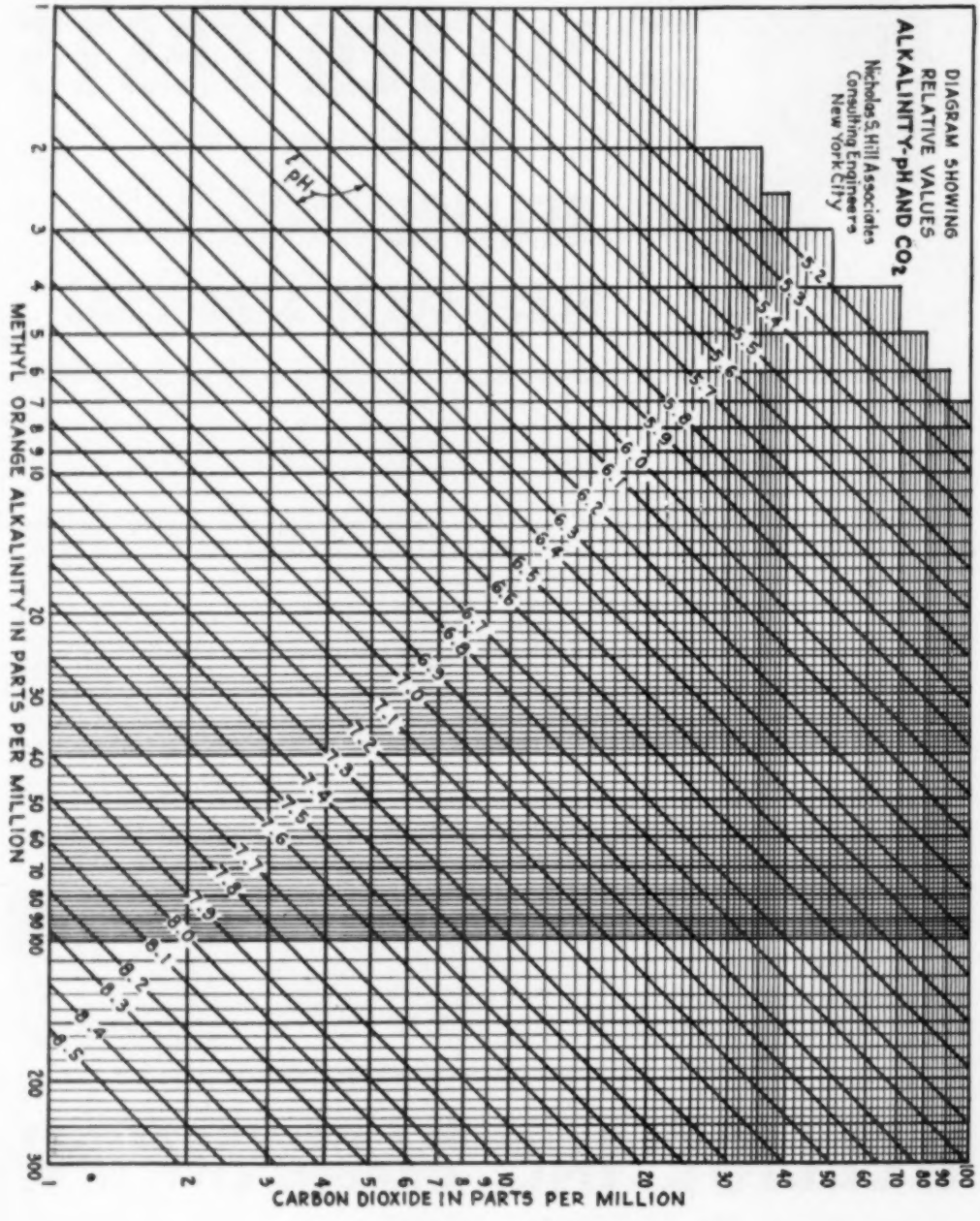
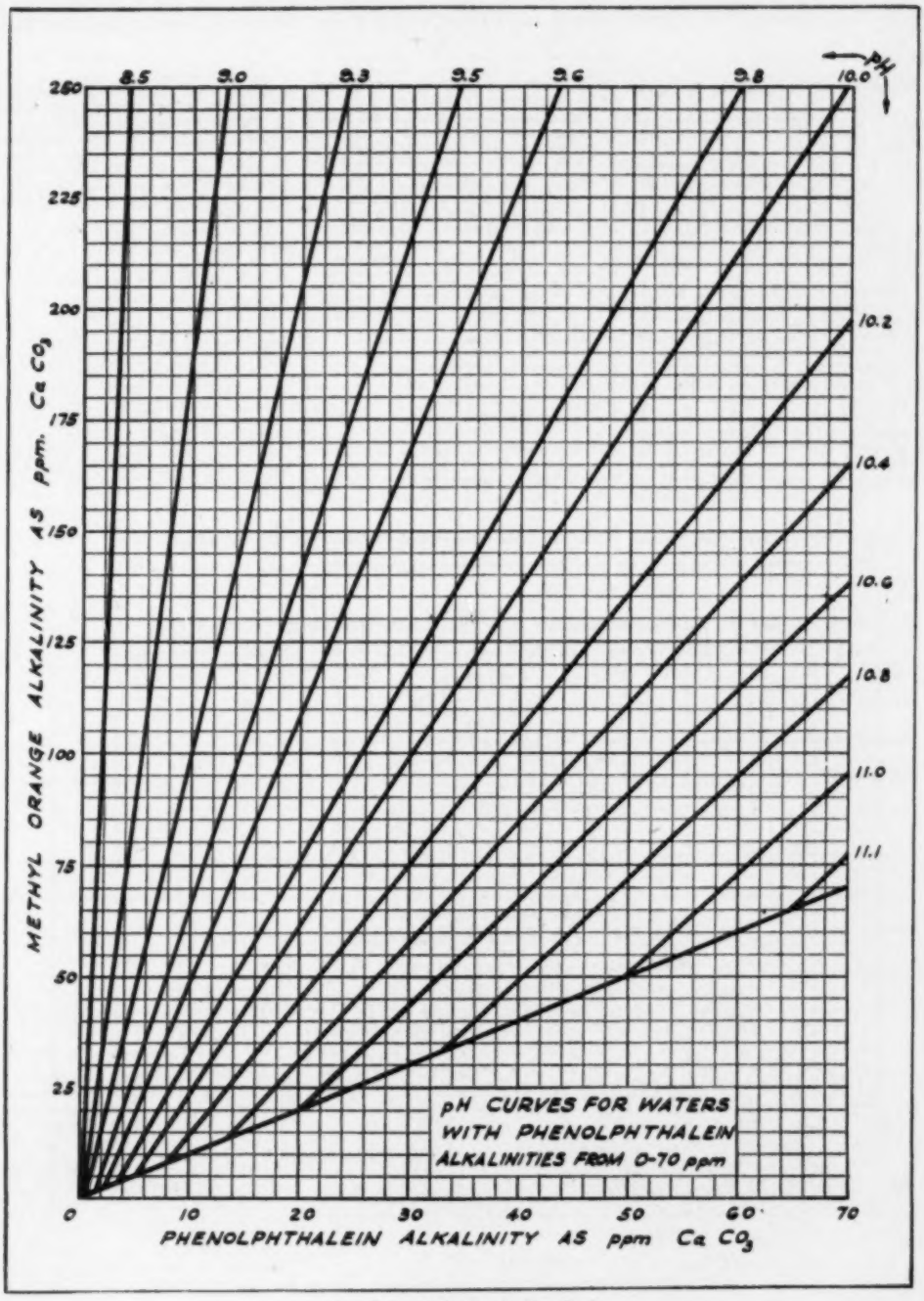
HEADQUARTERS FOR COLORIMETRIC APPARATUS AND COLOR STANDARDS

pH CONVERSION CHART

Note: This chart has an especial usefulness in determining free carbon-dioxide content of waters without making the tedious and frequently inaccurate CO_2 titration. Alkalinity and pH readings are more easily and accurately made. To find CO_2 content —Locate pH value diagonal; follow it to intersection with alkalinity value vertical. The horizontal line passing through this same point reveals the correct free CO_2 content. Courtesy Nicholas S. Hill Associates, New York City.



EFFECT OF CARBONATE AND BICARBONATE ALKALINITY ON pH



From Permutit Company's Data Book

GRAPHICAL APPROACH TO STATISTICS

By C. J. VELZ

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I—Nature and Variability of Data

SCIENCE and engineering today are all but buried beneath the mass of their own data. In fact, the mere accumulation of more and more data is too frequently regarded as research. Statistical evaluation offers the only means of condensing raw data to concise form, permitting significant interpretation. Statistics provides the tools sharp enough to dig into the old accumulations, extricate and bring to light some of the buried "gold."

It is the purpose of this series to encourage the use of statistics by presenting a few simplified graphical techniques readily usable in Sanitary Engineering, i.e. procedures employing different types of probability papers, graphical tests for statistical significance of series of data and trends, and evaluation of laboratory results.

To illustrate the uses of statistics in Sanitary Engineering consider one problem, that of interpretation of suspended solids determinations at a sewage treatment works. We all know that suspended solids are subject to considerable variation from day to day and from hour to hour. How can we best define and summarize these variations and detect real changes in the load? When is a change significant beyond that expected by chance variation alone? How many individual determinations must we make in order to have a reliable average? When are individual determinations out of line with what is normally expected? How can we make reliable comparisons between influent and effluent?

The proper evaluation of data in sewage works operation and stream pollution studies cannot be accomplished by simple mathematical averages of a series of analytical results. "Statistical evaluation offers the only means of condensing raw data to concise form, permitting significant interpretation," according to the author. This article on the "Graphical Approach to Statistics," has been prepared especially for *Water & Sewage Works* to show how the usual forbidding methods of statistics can be used by means of graphic solutions. These articles may well revolutionize future work in this field with particular reference to water and sewage analysis for chemical and bacteriological constituents.—The Editors.

For intelligent application of the graphical procedure, it is first necessary to gain fundamental concepts of the nature of variation of data and the laws of probability.

Definition

Statistics may be defined as the scientific collection and analysis of data, and the projection of estimates therefrom. Statistics is not an end in itself; rather it is an aid to judgment in arriving at valid conclusions, testing theories, measuring phenomena, discovering relationships, or projecting estimates under different conditions. The statistical method is an economical procedure for getting at the facts and determining their significance with confidence. In our enthu-

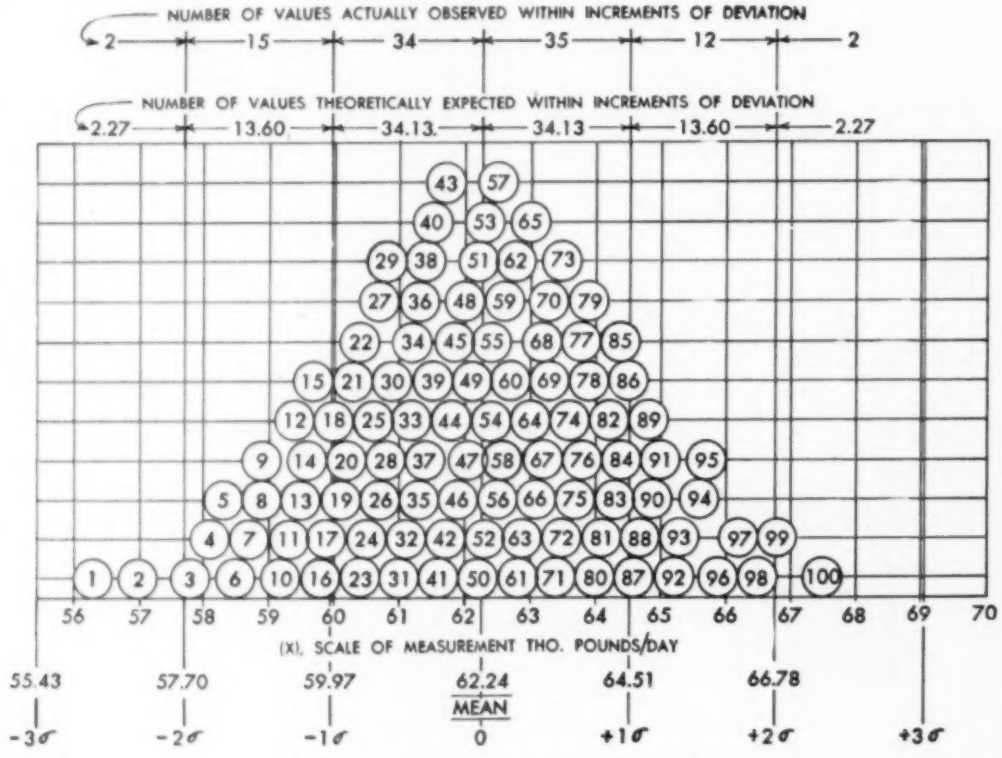


Fig. 1—Demonstration of the Normal Probability Curve
(Distribution of 100 suspended solids determinations; Mean 62.24 thd. pounds per day; Standard deviation 2.27 thd. pounds per day)

siasm over statistics it must be remembered that it is only a tool and is not a substitute for professional knowledge and experienced judgment. Sound judgments, however, cannot be made with confidence without the use of this tool.

Statistical Concepts

The whole concept of statistics is one of *variation*. If there were no variation in data there would be no need for statistical methods. This concept of variation is in conflict with most of the mathematics as it has been taught us. In mathematics we usually start with a preconceived theory which, if followed, automatically must lead to a single exact answer without any deviation. Such inflexible finality is not consistent with the facts of life as we *observe* them. Even with the most precise methods of measurement there is *always variation*. In statistical reasoning we start with observations and with full acceptance of their inevitable variation which leads not to a single answer but rather a range of answers.

For example, let us suppose we desire to know the weight of an object. A single careful measurement may be 10.1 milligrams, a second measurement made under the same circumstances may be 9.8, and similarly, repeated measurements will show other variations. With these variations in measurements the question arises, Which of these answers is correct? or, What is the exact true weight? The true weight remains unknown and at best can be only estimated. The best estimate is the average of the repeated measurements, in this case, say 10.0. But confidence in any estimate can be had only in defining not a single value but a *range* within which we believe the true weight lies.

From a statistical analysis of the variation of the measurements confidence and range can be related. We are confident of enclosing the true value 68 times in 100 within the range $10.0 \pm .1$ (9.9 to 10.1); or we are confident of enclosing the true value 997 times in 1,000 within the range $10.0 \pm .3$ (9.7 to 10.3). In the second instance our confidence is high; only 3 times out of 1,000 would we be wrong in believing that the true value was within this wider range. But we have gained this added confidence only at the expense of precision; we are less definite as to the exact true weight in the sense of a single value.

In fact, under this new concept we can never determine with finality the exact true weight, because as we narrow the range working toward a single value we lose confidence in enclosing it, with total loss of confidence if an attempt is made at expression as a single value. Thus in expressing measurements we always state a *range;* the mean plus or minus some increment of standard deviation, the increment dependent upon the degree of confidence desired.

The Nature of Variation

If a series of measurements, say weight, made on the same object are sorted in order of magnitude, it will be found that the results vary in a quite systematic manner. Many of the results will cluster near the midvalue and a few will be more or less evenly distributed with greater spread above and below the central majority. Another type of quantitative data consisting of a *sample* from a large population, universe or supply such as a single weight measurement of a number of such objects selected at random, will likewise portray this tendency toward central cluster and symmetrical spread.

If a large number of such measurements are made and plotted on the scale of measurements, each individually represented by a circle, a symmetrical bell-shaped pile develops as shown in Fig. 1. The center of each circle is vertically above the magnitude of its measurement on the (X) scale; the number in each circle is the rank of each measurement arranged in ascending order of magnitude. The measurements cluster so closely about the mean that it is necessary to pile up the circles in order to locate them opposite their position on the (X) scale, thus forming the bell-shaped curve or distribution. This frequency curve of distribution of measurements, referred to as the *Normal Probability Curve*, has definite characteristics with respect to the proportion of the measurements found in equal increments of scale as indicated by the numbers across the top of the pile. Those characteristics will be defined more precisely later.

Suffice to observe that the distribution is nicely symmetrical about a *centering value;* with the *deviations* above and below this value spreading out in a very orderly fashion. Other random samples taken from the same universe under the same conditions will reproduce quite similar distributions both as to centering position on the scale and as to deviation or spread. Measurements of different phenomena will develop similar bell-shaped distributions but it will be observed that each has its own centering value and that some vary in the degree of spread or deviation about their central values as illustrated in Fig. 2.

Centering Values

Three centering values are commonly employed: the *Median*, the *Mode* and the *Mean*. The median value is the value exceeded by ½ of the values and of which ½ of the values fall short. It represents the series, if at all, by virtue of its position of dividing the series in half. The mode is the value in the series most frequently repeated and around which other values cluster most densely. It is the high point in the distribution irrespective of the number of terms above and below it. The mean is a simple arithmetic average of the series of data represented by the *sum of the individual measurements divided by the number of observations*. Where the distribution is *normal* (symmetrical), the median, the mode and the mean are identical and coincide. The mean is the most useful centering value and is most frequently employed.

However, an average by itself is a dangerous value. Too frequently series of data are summarized merely by an "average" (the mean) without designating the number of measurements or the nature of variation or spread in the data. For example, consider the following three series of data, X, Y, and Z, which have the same average:

(1) X comprised of 2 values, 1 and 99; average = 50.
(2) Y comprised of 19 values ranging from 10 to 90; average = 50.
(3) Z comprised of 19 values ranging from 47 to 53; average = 50.

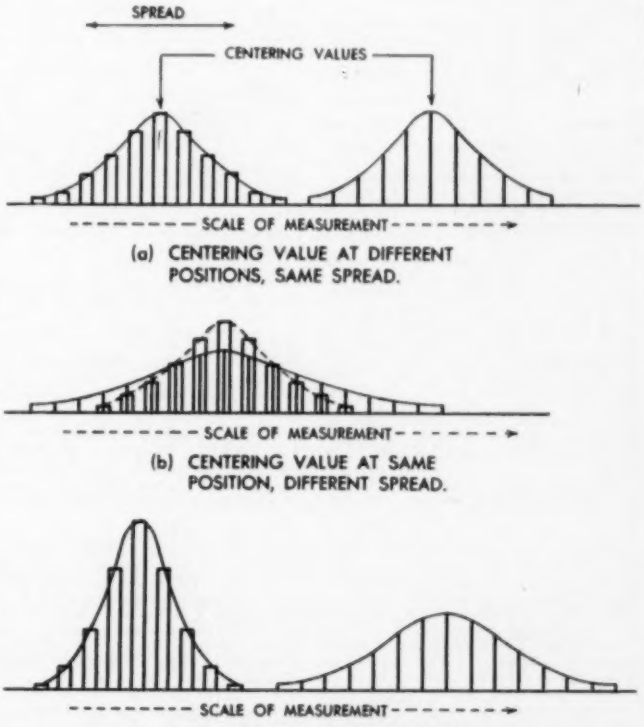

SPREAD
CENTERING VALUES
SCALE OF MEASUREMENT
(a) CENTERING VALUE AT DIFFERENT POSITIONS, SAME SPREAD.
SCALE OF MEASUREMENT
(b) CENTERING VALUE AT SAME POSITION, DIFFERENT SPREAD.
SCALE OF MEASUREMENT
(c) CENTERING VALUE AT DIFFERENT POSITION, DIFFERENT SPREAD.

Fig. 2—Bell-shaped Distributions Show Centering Tendencies but Vary in the Degree of Spread or Deviation

While all produce the same average (50), it is not difficult to see that the three averages come from quite different data. In the first instance, two measurements hardly give meaning to an average, particularly when they have a great spread; in the second and third instances, while both have the same number of measurements (19) and the same average (50), the second has a wide spread ranging from 10 to 90, while in the third the data are compact, with a spread ranging from 47 to 53.

Deviation from the Central Value

In addition to the mean and the number of measurements it is necessary to know something of the nature of deviations of measurements about the central value.

The Standard Deviation, σ (Sigma), is the fundamental measure of variation which constitutes the major "building block" in all statistical procedures. It is the root mean square deviation obtained by squaring each individual deviation from the mean, summing, dividing by the number of measurements and extracting the square root of this mean square.

$$\sigma = \sqrt{\frac{\Sigma(X - \bar{X})^2}{n}} \qquad \text{Eq. 1}$$

(There are various other transformations of this equation which are more useful if computations are made by machine; also a simple graphical method of obtaining the standard deviation will be given in the next article.)

The standard deviation is important because, through it, the fundamental characteristics of the normal probability curve are defined and precision can be related to probability or a confidence level.

Probability

As a basis for understanding the graphical applications of statistical procedures, which will be presented in subsequent articles, and the significance of the standard deviation as a measure of variation, it will be necessary to gain a concept of *Probability*.

There are two concepts of probability, the one based upon what *can* occur and the other based upon what *has* occurred. If an event can occur or has occurred in (a) ways and can fail or has failed in (b) ways, then the probability of a success is $a/(a + b)$, which is a ratio of the number of ways in which an event can occur or has occurred to the total number of ways of occurrence, each being equally likely to occur. Probability is expressed as a ratio and ranges from *zero* to *unity*; zero designating impossibility; unity designating certainty.

The first concept, based upon what *can* occur, is referred to as *a priori* probability. In tossing a coin there are two ways in which an event can occur, either a head or a tail. The probability of a specified event, head, is therefore ½ or 0.5. There are six ways in which a die can fall. The probability of the event, an ace, is therefore 1/6. These are probabilities before a trial, based purely upon what *can* occur.

The second concept, based upon what *has* occurred, is referred to as *a posteriori* probability, probability after the trial. A coin is tossed 1,000 times and the event, a head, has been observed to occur 506 times. The a posteriori probability of a head, based upon what has occurred, is 506/1,000 or 0.506, as compared with a priori probability based upon what can occur of 0.5.

The a priori or true probability of a universe can exist but it cannot be measured. Repeated random samples drawn from a universe show results varying about the true value, results from the small samples showing greater variation than those from the larger samples. Or as the number of trials approaches infinity the a posteriori probability as determined from the observations approaches the true a priori probability.

Numerical Expressions of Probability

1. The sum of the probabilities of occurrence of a complete and mutually exclusive set of events is unity. Impossibility has a probability of exactly zero. The entire range of probabilities extends from impossibility to certainty or numerically from 0 to 1.

2. If the probability of success is p and of failure q then $p + q = 1$; and $1 - p = q$; and $1 - q = p$.

3. The probability of *either* one *or* another of mutually exclusive events occurring is the sum of their individual probabilities. Probability of drawing a spade *or* a heart: $\frac{13}{52} + \frac{13}{52} = 0.5$; of drawing a spade, a heart or a club: $\frac{13}{52} + \frac{13}{52} + \frac{13}{52} = 0.75$.

4. The probability of occurrence of a compound event composed of two or more independent events is the product of the individual probabilities. What is the probability of *two* heads in *two* throws of a coin? (One head on the first throw and one head on the second throw.)

Probability of head on 1st throw = 0.5
Probability of head on 2nd throw = 0.5
Probability of two heads on two consecutive throws $0.5 \times 0.5 = 0.25$

Relation of the Standard Deviation to the Normal Probability Curve

The normal probability curve is a standardized form of distribution where the scale of measurement is in terms of the standard deviation measured from the center of the distribution as the origin. For example, referring to Fig. 1, the (X) scale is weight in thousand pounds per day; and the corresponding (X′) scale is in terms of the standard deviation. The zero of the X′ scale is opposite the center of the distribution, the mean 62.24 thousand pounds per day. Unit distance on the X′ scale is equivalent to a standard deviation, 2.27 thousand pounds per day, measured along the X scale but labeled $+1\sigma$, $+2\sigma$, $+3\sigma$ and -1σ, -2σ, -3σ, on the X′ scale. To convert a series of scaled measurements (X) to the standard probability scale X′ it is necessary to know the mean ($\bar{X}$) and the standard deviation (σ). The mean ($\bar{X}$) is the simple arithmetic average and the standard deviation can be computed from the data or, as will be illustrated later, readily obtained graphically.

The significance of the standard deviation (σ) as a measure of variation is apparent from the following analysis of the distribution of the 100 measurements on Fig. 1. Extending two vertical lines at $+1\sigma$ and -1σ on either side of the mean, we count 69 of the total 100 measurements falling within this range, and 31 fall without, 14 above and 17 below. Probability of measurements falling within this range based upon what has occurred is 69/100 or 69 per cent; and of falling without, 31/100 or 31 per cent. Similarly, we count 96 measurements within the range of the mean $\pm 2\sigma$, and 4 measurements without, 2 above and 2 below. The probability of measurements falling within is 96/100 or 96 per cent, and of falling without, 4/100 or 4 per cent.

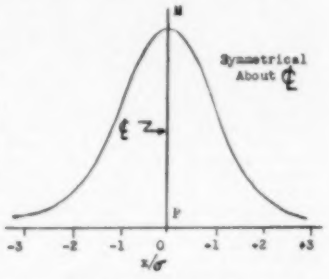
Characteristics of the Normal Probability Curve

These results are based upon a sample of 100 measurements. As the number of measurements is increased the a posteriori distribution approaches the a priori distribution defined by the Normal Probability Curve. The a priori probability of measurements falling within any range are given by the area under the curve between the limits of the range defined in terms of standard deviations from the mean. These areas have been computed for any increment of deviation and are available in tables.

One useful form is the Integration Graph shown in Fig. 3. The areas are given between the central value (the mean) and x/σ (deviation in terms of standard deviation) measured only in one direction from the mean.

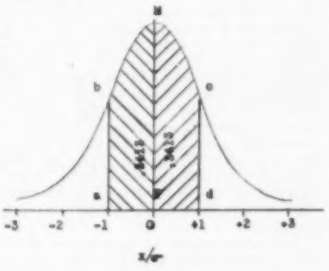
The Probability Curve has the following six characteristics:

1. All events are distributed symmetrically about the "mean" or the "most probable" M.P. value.



2. The Probability Integral for the complete distribution of events is the area between $\pm \infty$ which is unity. Pb of all events = 1.0.

3. The Probability Integral for all events between the limits of $\pm 1\sigma$ (Dev/σ = 1) from the M.P. value is the area (abcd) which from the Integration Graph is $2 \times 0.3413 = 0.6826$. Thus 68.26% of all events lie within a range of $\pm 1\sigma$ from the M.P. value and 31.74% of the events lie without this range.



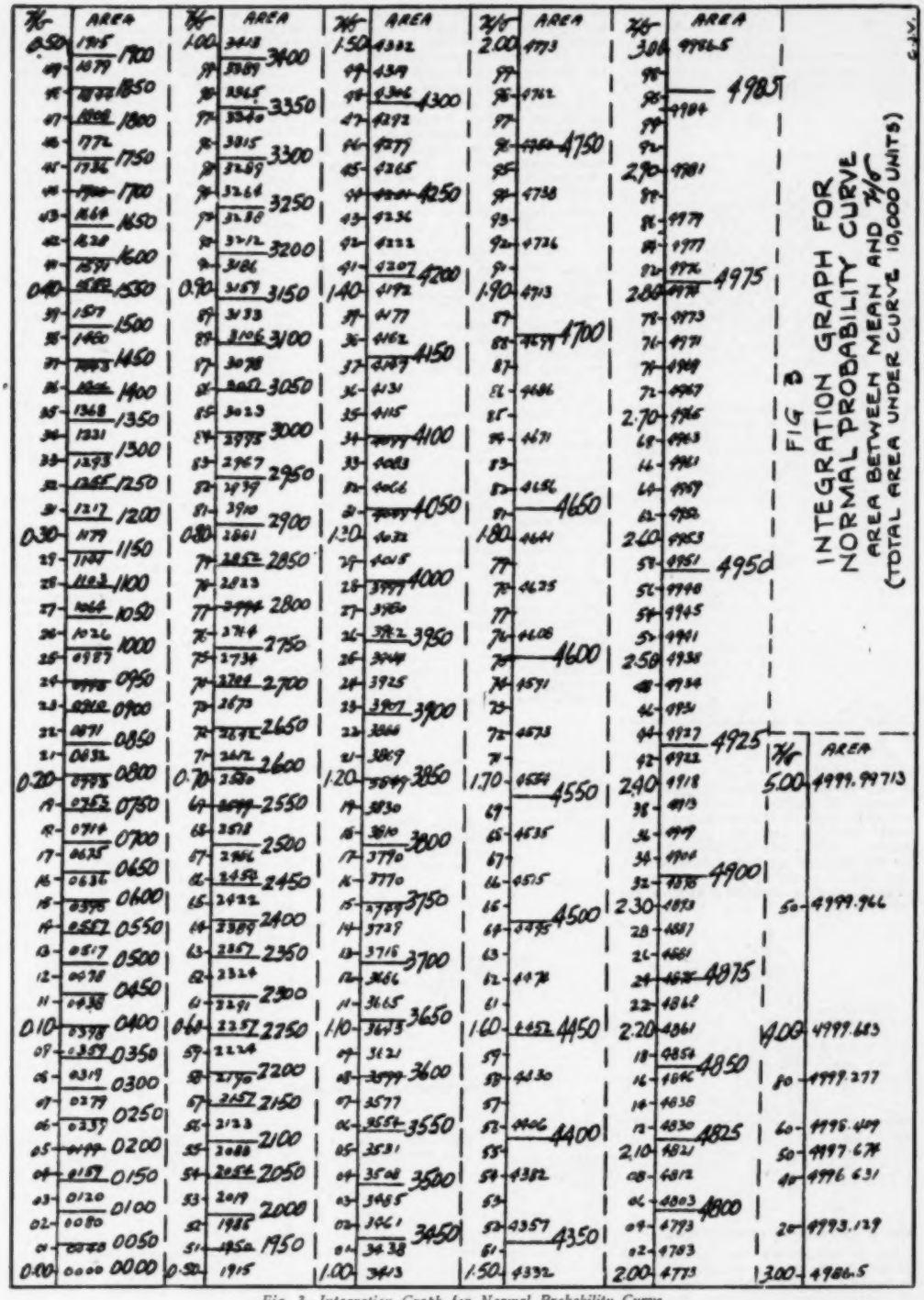
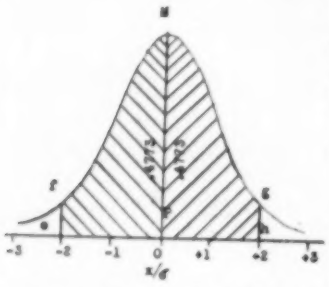
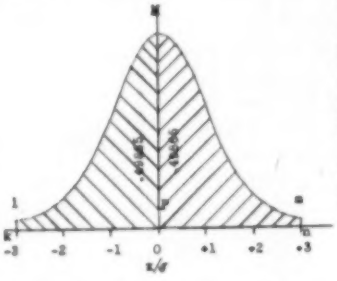


Fig. 3—Integration Graph for Normal Probability Curve
(Area between mean and x/σ. Total area under curve 10,000 units)

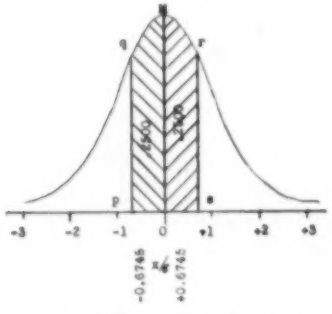
4. The Probability Integral for all events between the limits of $\pm 2\sigma$ (Dev/σ = 2) from the M.P. value is the area (efgh) which from the integration graph is 2 × 0.4773 = 0.9546. 95.46% of all events lie within a range of $\pm 2\sigma$ from the M.P. and 4.54% of events lie without this range.



5. The Probability Integral for all events between the limits of $\pm 3\sigma$ (Dev/σ = 3) from the M.P. is the area (klmn) which from the integration graph is 2 × 0.49865 = 0.9973. 99.73% of all events lie within the range of $\pm 3\sigma$ from the M.P. and 0.27% of the events lie without this range.



6. The Probability Integral for all events between the limits of $\pm 0.6745\sigma$ (Dev/σ = .6745) from the M.P. is the area (pqrs) which from the integration graph is 2 × 0.2500 = 0.5000. 50% of all events lie within the range of $\pm 0.6745\sigma$ from the M.P. and 50% of events lie without this range. This is sometimes referred to as the range of Probable Error (P.E.).



Uses of Probability Integration Graph

Let us suppose we wish to define the quality of effluent of a sedimentation tank in terms of suspended solids. The mean of 30 determinations is 102.0 ppm, but values vary about the mean with a standard deviation from the mean (σ) of 5.5 ppm. From what has been said heretofore, we must define quality of the effluent by a range and we wish to know the confidence of enclosing the quality in that range.

For example, suppose we make the statement that the quality of effluent is within the range of 102.0 ± 10 ppm.; what is our confidence that this range encloses the quality? or, what risk do we take in having the quality measurement fall outside this range? This we determine from the integration graph:

Deviation from the mean = × = 10 ppm;
Deviation from the mean in terms of standard deviation, $x/\sigma = \frac{10}{5.5} = 1.82$.

Opposite x/σ of 1.82 on the Integration Graph, Fig. 3, read area 46.56 per cent or probability for the range, Mean ± 1.82σ, is 2 × 46.56 per cent or 93.12 per cent.

We are about 93 per cent confident of enclosing the quality of the effluent within the range of 102.0 ± 10 ppm. In accepting this range as defining the quality we run the risk of being wrong about 7 times in 100, as 7 times in 100, deviations greater than ± 10 ppm are expected.

Again suppose we do not wish to be wrong in our range of quality more often than once in 100, then in 99 times in 100 we must be right. This requires an area in one direction from the mean of 99/2 or 49.5 per cent. Opposite area of 49.5 per cent on the Integration graph, Fig. 3, read $\times/\sigma$ of 2.567. The range then is defined by the mean ± 2.567σ or 102.0 ± 2.567 × 5.5, 102.0 ± 14.1 ppm. In other words, in saying that the effluent quality is 102.0 ± 14.1 we are 99 per cent confident of being right and only once in 100 would we expect to be wrong by having quality fall outside of this range.

If we are willing to accept even chance of being right or wrong, the range can be narrowed. This requires an area in one direction from the mean of 50/2 or 25 per cent. Opposite area of 25 per cent on the Integration Graph, Fig. 3, read $\times/\sigma$ of 0.6745. The range then is the mean ± $.6745\sigma$ or 102.0 ± .6745 × 5.5 ppm = 102.0 ± 3.7. Now we have a narrower range but we do not have great confidence in it because half of the time quality of the effluent is expected to fall outside the limits of this narrower range.

In the next article we shall transform the bell-shaped probability curve and its integration graph into a straight-line on probability paper so that answers to questions such as these as well as others can be directly read at a glance.

II—Normal Probability Paper

This section will deal with the construction and use of normal probability paper. The bell-shaped probability curve developed in the previous article can be reduced to a straight line in the form of probability paper which facilitates the graphical solutions of many statistical problems.

The first step in the construction of normal probability paper is the transformation of the bell-shaped distribution curve to the probability summation or the ogee curve. The bell-shaped curve and its integration graph, Fig. 3, give the areas of the central portion about the mean working outward toward the tail of the curve. The probability summation or ogee curve starts in the extreme left tail at minus infinity and sums the area by successive intervals toward the right. These two forms are shown in Fig. 4 (A), the bell-shaped distribution curve, and (B) the summation or ogee curve, both referred to an X'-axis scale in deviations from the mean expressed in terms of standard deviation.

The ogee curve can be constructed readily from the increments of area obtained from the integration graph, Fig. 3. The percentage of the area up to any deviation below the mean is simply obtained by sub-

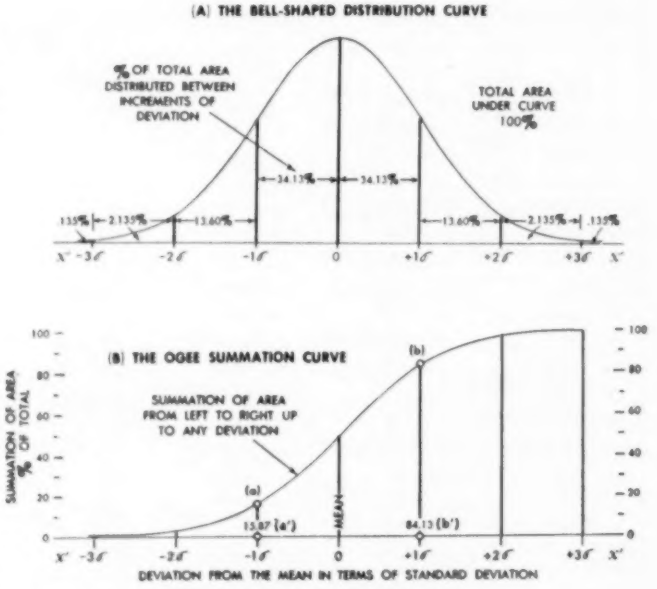


Fig. 4—The Normal Probability Curve

tracting from 50 per cent, the area obtained from the integration graph for that deviation; and for deviations above the mean, by adding 50 per cent to the areas of the integration graph, Fig. 3. For example, the summation of area up to a deviation of -1σ below the mean is (50 − 34.13) or 15.87 per cent, while the summation of area up to $+1\sigma$ above the mean is (50 + 34.13) or 84.13 per cent.

These two points are located on Fig. 4 (B) at (a) and (b) and similarly any number of other transformations can be made, forming a complete smooth ogee curve.

The next step is to reduce the ogee probability summation curve to a straight line. This is simply done by projecting the points on the ogee curve vertically to the linear X'-axis scale and writing opposite each its corresponding percentage. For example, point (a) is projected to (a') and writing its probability summation 15.87 per cent; (b) projected to (b') and writing 84.13 per cent; etc. Figure 5 (A) is such a scale enlarged and Fig. 5 (B) is a scale of a size convenient for transfer to an 8½ x 11 in. sheet. These scales constitute the X-axis of *normal probability paper*.

Since the probability summation is the cumulative area from left to right, it represents probability *equal to or less than*. This is a useful expression as it affords an opportunity to determine readily the probability of not exceeding a certain magnitude of measurement.

For example, arranging the series of data of suspended solids determination of sewage (Table 1) in ascending order of magnitude automatically places the data in the order of their probability *equal to or less than*. Thus, by the simple technque of arranging data in order of magnitude we place them in the order of their position on the probability summation scale of normal probability paper.

If the distribution is truly normal, these values so arranged form a perfect straight line on the paper. Obviously, it is easier to deal with a straight line than the complicated bell-shaped curve. There remains, however, the problem of determining the plotting position of a number of measurements on the probability summation scale.

The Plotting Position

Let us refer for a moment to the definition of probability given in the first article, namely, the ratio of the number of occurrences divided by the total number of trials. Applying this to the series of 20 determinations of suspended solids of sewage shown in Table 1 leads to the following:

CASE I. The probability of a value equal to or less than the smallest value, the first, would be 1/20 or 5 per cent; two values were observed equal to or less than 103.4 thousand pounds, probability 2/20 or 10 per cent; and finally 20 values are equal to or less than the largest value or 20/20 or 100 per cent. Immediately we face the dilemma, if we plot the first point at 5 per cent on the probability summation we will not be able to plot the last point because it is positioned at 100 per cent which is located at plus infinity, completely beyond our scale. This is equivalent to saying that the largest value which was actually observed to occur once in 20 would occur only once in an infinite number of observations.

CASE II. Similarly, if we reverse the scale and start at the large end and number the values in descending order of magnitude and express probability as equal to or greater than, the largest value would be plotted at 1/20 or 5 per cent, but now we would be unable to plot the smallest value as its probability would be 20/20 or 100 per cent which would be located at minus infinity, completely off the scale.

CASE III. Hazen[1] suggested what appeared to be solution; plot the first value at the midpoint of equal increments on the scale of 100 per cent. For example, the increment for the 20 points would be 100/20 or 5 per cent. The first point being plotted at ½ of 5 or 2.5 per cent; the second point at 2.5 + 5 per cent or 7.5 per cent; etc., successively to the 20th point at 97.5 per cent. This permits plotting all of the values on the scale, and at first thought appears to solve the problem; but this does violence to the probability of the extreme values, the first and last points. Placing the smallest value of 20 values in a position on the probability scale at 2.5 per cent is ascribing to it a probability as though it were the smallest value of a series of 40 measurements, 100/2.5. In like manner, placing the largest value of 20 at 97.5 per cent is to ascribe to it a position as though it were the largest value of a series of 40 measurements. Obviously, such positions of the probability of the end points cannot be accepted.

CASE IV. Theoretically, the plotting position for the mean of any series regardless of number of values is at 50 per cent and ½ of the values should be above and ½ below. If the mean is considered as part of the series the number of plotting positions becomes n + 1. On this basis the mean plotting positions of the observed values are obtained from the relation $\frac{m}{n+1}$ in which m is the serial number of the measurements arranged in ascending order of magnitude and n is the total number of measured values to be plotted. Thus, the plotting position for the first value of a series of 20 values would be 1/21 or 4.77 per cent; the 2nd, 2/21 or 9.53 per cent, etc.; and the 20th value, 20/21 or 95.23 per cent.

Under these conditions it will be noted that the first and last values in the series of 20 will be plotted in positions as though they are the smallest and largest values in a series of 21 values (100/4.77), with 10 values above 50 per cent and 10 values below 50 per cent. These plotting positions are more consistent with theory and with the facts as observed, and Case IV is therefore recommended.

Plotting on Normal Probability Paper

In summary, the procedure for plotting observed or experimental data on normal probability paper is as follows:

1. Arrange the data in order of ascending magnitude.

2. Assign a serial number "m" to each of the n values 1, 2, 3.....n.

3. Compute the plotting position of each serial value, giving the probability equal to or less than for each value by the expression $\frac{m}{n+1}$ expressing the ratio as a percentage.

4. The scale by which the observed or experimental data were measured is then laid off on the Y-axis and the plotting positions are the probability scale on the X-axis. The points are plotted, using these (X, Y) coordinates.

Interpretation:

1. If a straight line develops in the plotting, it indicates that the data have a normal distribution; that is, in accordance with the theory of probability we expect results distributed in this manner.

2. If a straight line does not develop in the plotting, we suspect that something is changed in the conditions affecting the observed measurements beyond what is normally expected. This might mean carelessness in measurements or it may mean that we had not measured the same characteristics under the same conditions or that we had been measuring at the same time two or more distinctly different things. These very useful interpretations are immediately visually apparent in the graphical presentation on probability paper.

Graphical Determination of the Mean and the Standard Deviation

Following the above procedure, the 20 determinations of suspended solids of sewage shown in Table 1 are plotted on normal probability paper, Fig. 6. Inasmuch as the distribution forms a straight line (is normal), it is readily possible to determine graphically (1) the mean of the series and (2) the standard deviation from the mean, measuring the degree of variation among the data.

The mean is at once determined where

[1]Hazen Allen. *Flood Flows*, John Wiley & Sons. 1930.

Table 1

SUSPENDED SOLIDS IN DAILY RAW SEWAGE FLOW

(Data courtesy Geo. Fynn and Geo. E. Symons, Buffalo Sewer Authority)

Suspended Solids 1000 lb./Day arranged in order of magnitude	Rank Serial No. (m)	Plotting position, Probability—Equal to or less than (m/(n+1) in %
(1)	(2)	(3)
72.6	1	4.8
103.4	2	9.5
112.8	3	14.3
117.1	4	19.0
120.7	5	23.8
127.9	6	28.6
128.9	7	33.3
131.3	8	38.1
135.4	9	42.9
137.5	10	47.6
143.9	11	52.4
148.4	12	57.1
148.8	13	61.9
153.9	14	66.7
155.2	15	71.4
170.9	16	76.2
176.0	17	81.0
185.0	18	85.7
188.6	19	90.5
194.2	20 = n	95.2

the straight line of the distribution intersects the vertical line extending from 50 per cent on the X-axis at (a). The magnitude of the mean is read directly on the Y-axis as 143 thousand pounds per day.

The standard deviation is the slope ($\triangle y/\triangle x'$) of the distribution line on probability paper. If there were no variation in the individual measurements, all values would be exactly alike and would plot exactly as a horizontal straight line. The angle from the horizontal position, therefore, is a measure of the degree of variability of the data; the steeper the slope the greater the variability.

Since the probability summation scale was constructed linearly in terms of standard deviation from the mean, the slope of the distribution line measured on the standard deviation scale at once provides the standard deviation. Extending vertically from $+1\sigma$, one standard deviation from the mean, $\triangle y$, can be read directly from the graph on the Y scale as 30 thousand pounds per day. (The slope (σ) can be determined from any corresponding $\triangle y/\triangle x'$ along the line.)

In addition to visually summarizing our data, graphically supplying the mean and the standard deviation from the mean, plotting on normal probability paper affords an opportunity to extend our series beyond the number of observations and determine the expected magnitude of a value at any probability equal to or less than. For example, referring to Fig. 6, if we wish to know the expected magnitude of a value that not more than 1 per cent of the values are equal to or greater than, that is 99 per cent equal to or less than, we extend vertically from 99 per cent on the X-axis to intersect the distribution line at (b) reading on the Y-axis 212 thousand pounds per day.

We also can make interpretations concerning confidence and precision in any range of deviation about the mean. For example, we are 68 per cent confident of enclosing the quality within the range of 113 to 173 thousand pounds per day, located directly on the distribution line at the points (c) and (d), vertical extensions from 16 and 84 per cent, that is 34 per cent on either side of the mean. Similarly, we are 90 per cent confident of enclosing the quality within the range of 93 to 193 thousand pounds per day, located by (e) and (f), vertical extensions from 5 and 95 per cent on the X-axis, 45 per cent on either side of the mean.

Thus from the plot on probability paper we can read directly the probability of any range of deviation or the probability of not exceeding any magnitude of measurement.

Plotting a Large Series

The example of Fig. 6 deals with a small number of measurements, and no difficulty is encountered in plotting each individual measurement. In the event the series of measurements comprises a large number of values it becomes confusing to plot each individual value, and it is preferable to *group* the data. For example, suppose we have taken during a year 500 measurements of hardness of a softened water supply and we wish to summarize the data and define the variation by plotting on probability paper. The scale of measurement in ppm. has been divided into 5 ppm. intervals and the hardness results have been sorted into each group as shown in Table 2.

Summing the number of values found in each group gives the number less than the

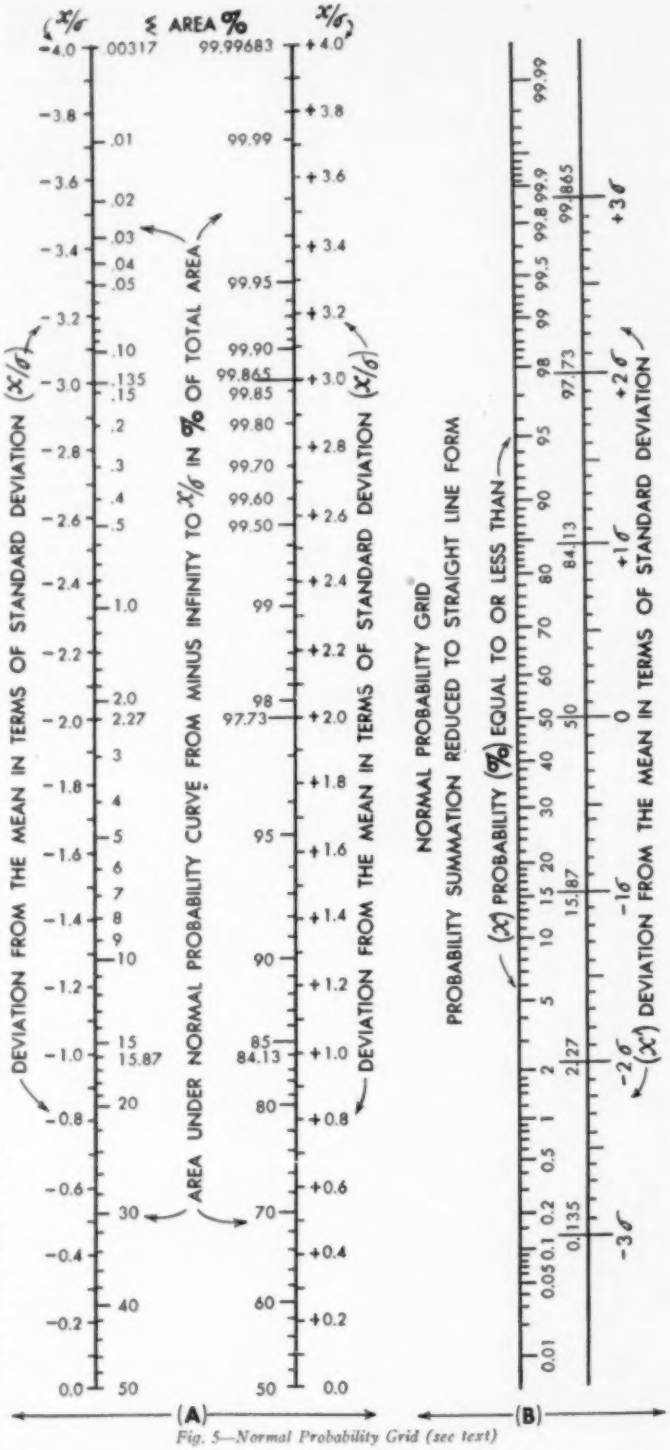

DEVIATION FROM THE MEAN IN TERMS OF STANDARD DEVIATION (x/σ)
AREA UNDER NORMAL PROBABILITY CURVE FROM MINUS INFINITY TO x/σ IN % OF TOTAL AREA
DEVIATION FROM THE MEAN IN TERMS OF STANDARD DEVIATION (x/σ)
NORMAL PROBABILITY GRID
PROBABILITY SUMMATION REDUCED TO STRAIGHT LINE FORM
(x) PROBABILITY (%) EQUAL TO OR LESS THAN
(x') DEVIATION FROM THE MEAN IN TERMS OF STANDARD DEVIATION
(A)
(B)

Fig. 5—Normal Probability Grid (see text)

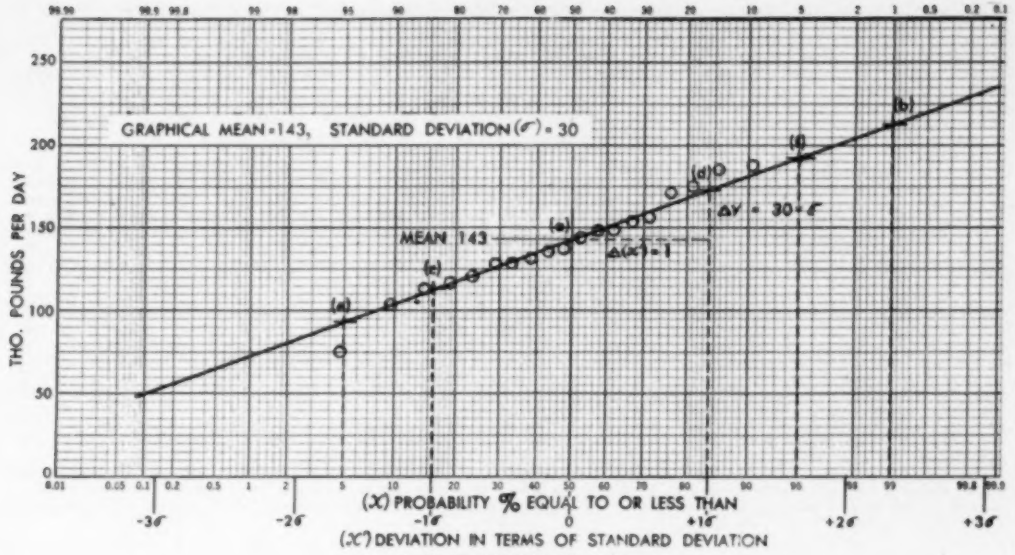


Fig. 6—Suspended Solids—Raw Sewage (Buffalo Sewer Authority)

divisions of the group intervals, which corresponds to the serial number (m) as shown in Column 3. The plotting position (Column 4) on the X-axis of the probability paper is $m/(n+1)$, expressed as per cent, where n is 500, the total number of values. The coordinates (Y) Column 1 and (X) Column 4 are then plotted on probability paper as shown in Fig. 7. The straight line formed summarizing the entire 500 values indicates a normal distribution, with a mean located at (a) of 63.6 ppm. and a slope or standard deviation from the mean of 11.4 ppm. The probability of any range, or of not exceeding any magnitude of measurement can be read directly from the graph. For example, we expect: not more than 1 per cent to exceed 90 ppm. located at (b); 1 per cent less than 37.3 ppm. located at (c); and 50 per cent within the range 56.0 to 71.3 ppm. about the mean between (d) and (e).

Reproducing a Series of Data

There are many occasions when we wish to reproduce graphically on probability paper a series of data from a published summary which does not tabulate each individual value. For example, if we are given the mean, the number of measurements and the standard deviation from the mean, it is a very simple operation to reconstruct on probability paper the expected normal distribution of the individual values of the series. This is just the reverse process of plotting a series of given data. For example, we are given the summary of a series of B.O.D. determinations, the number of measurements (n) 24, the mean ($\bar{Y}$) of 10.0 ppm., and the standard deviation (σ) from the mean of 1.57 ppm. The series is reproduced on Fig. 8 as follows:

Locate the mean on the Y-axis and draw a horizontal line to intersect with the vertical line, extended from 50 per cent on the X-axis at (a). This is the midpoint of our distribution. From this point lay off a slope $\Delta y/\Delta X'$ equal to the standard deviation 1.57, locating point (b). Draw a straight line from point (b) through the mean (a). This line represents the most probable distribution of the series of 24 individual measurements. If the original distribution was truly normal then the most probable values of each measurement would be located where $m/(n+1)$ or $m/(24+1)$ expressed in per cent extended vertically cut the line.

With this reconstruction we now can make any interpretations concerning confidence and range or probability of not exceeding any magnitude of measurement just as though we had been given the original data.

Thus far we have dealt with data that are normal, symmetrical about the central value and plot as straight lines. In the next article we shall deal with *skewed* distributions, such as selected extreme values, floods, droughts, and storm rainfall intensities.

III—Use of Skewed Probability Paper

This section will deal with skewed probability paper as applied to series of extreme values such as floods, droughts, or storm rainfall intensities. It is well known that extremes of hydrologic phenomena such as floods and droughts do not follow a normal symmetrical distribution, but rather are skewed (the more severe values deviate beyond the mean to a much greater extent than the less severe values deviate below it). Gumbel* developed a standard skewed distribution based upon the theory of largest values which when reduced to straight line form on special probability paper as suggested by Powell†, simplifies and facilitates the graphical solution of many statistical problems dealing with series of extreme values.

A comparison of the normal probability curve and Gumbel's standard skewed distribution of largest values is shown on Fig.

Table 2

HARDNESS OF SOFTENED WATER SUPPLY—1949

Group Hardness ppm (Y) (1)	Frequency (2)	Summation of Frequency (m) (3)	Probability (%) equal to or less than [m/(n+1) as %] (X) (4)
30 —34	2	2	0.4
35 —39	6	8	1.60
40 —44	16	24	4.8
45 —49	32	56	11.2
50.0—54	53	109	21.8
55.0—59	74	183	36.5
60.0—64	87	270	53.8
65.0—69	85	355	70.9
70.0—74	66	421	84.0
75.0—79	42	463	92.4
80.0—84	22	485	96.8
85.0—89	10	495	98.8
90.0—94	4	499	99.60
95.0—99	1	500	99.80
	n = 500		

*Gumbel, E. J. "The Return Period of Flood Flows," Annals of Mathematical Statistics, *12*, 163 (1941)

†Powell, R. W. "A Simple Method of Estimating Flood Frequencies," Civil Engineering, *13*:105 (1943)

y. On Fig. 9 (a) is the normal probability curve, which is perfectly symmetrical, with the mean and mode coinciding at the midpoint. Fig. 9 (b) is Gumbel's skewed distribution, which is asymmetrical, rising sharply to the peak and then falling off gradually in a long tail to the right, with the mode to the left of the mean. As with the normal curve, the probability of events is represented by the area under segments of the curve, total area being unity or 100 per cent. Gumbel has given these areas for increments of the curve and by summing from left to right a probability summation scale is obtained for the skewed distribution similar to that developed in the preceding article for normal probability paper.

Fig. 10 shows such a probability summation arranged to form a standard skewed probability paper applicable to series of extreme values. The ordinate (Y) is a linear scale assigned to the observed extreme values. Scale X is the probability summation scale giving the probability of a value *equal to or less than* a certain value Y. The X' scale is introduced for linearity and as an aid in fitting a straight line, which will be illustrated later. T_a scale at the top is the "Return Period." If the observations are equally spaced in time and the unit of time is taken as the interval between two successive observations, the Return Period, T_a, is defined as the mean number of observations, or average time, necessary to obtain once a value equal to or greater than a certain value Y.

$$T_a = \left(\frac{1}{1-X}\right)$$

Maximum and Minimum Series

Gumbel's skewed probability paper is applicable to series of minimum values as well as maximum values providing the data are arranged in order of severity rather than magnitude, starting with the least severe value and ending with the most severe. In dealing with maximum series, such as floods, the least severe value would be the smallest observed flood, and the most severe value would be the largest observed flood. However, in dealing with minimum data, such as droughts expressed in cfs, the least severe drought would be the largest cfs among the observed droughts and the most severe drought would be the smallest cfs among the observed values, just the reverse of floods. This places the most severe flood and the most severe drought in the same position in terms of probability of severity. Thus by the simple technique of arranging maximum or minimum data in order of *severity* we place them in order of their position on the probability summation scale of the skewed probability paper.

Series of data that are truly extreme values will plot as a straight line on the skewed probability paper which facilitates interpolation and extrapolation. From such a straight line, probability of any severity can readily be determined graphically.

The Plotting Position

In the previous article the problem of the plotting position on the probability summation scale was discussed recommending $m/(n+1)$. This simple relation may also be employed for series of extreme values where m is now the serial number of data arranged in order of severity and n is the total number of values to be plotted.

Gumbel, however, has suggested a refinement which is recommended especially when dealing with a small series of say less than 20 observations. He develops the probability of the most probable least severe and most probable most severe value as the plotting position of the two extreme observations m_1 and m_n; and calculates the remaining (n-2) plotting positions by dividing the intervening interval into (n-1) equal units.

The plotting position for the least severe and the most severe values are complex functions of n, the number of observations,

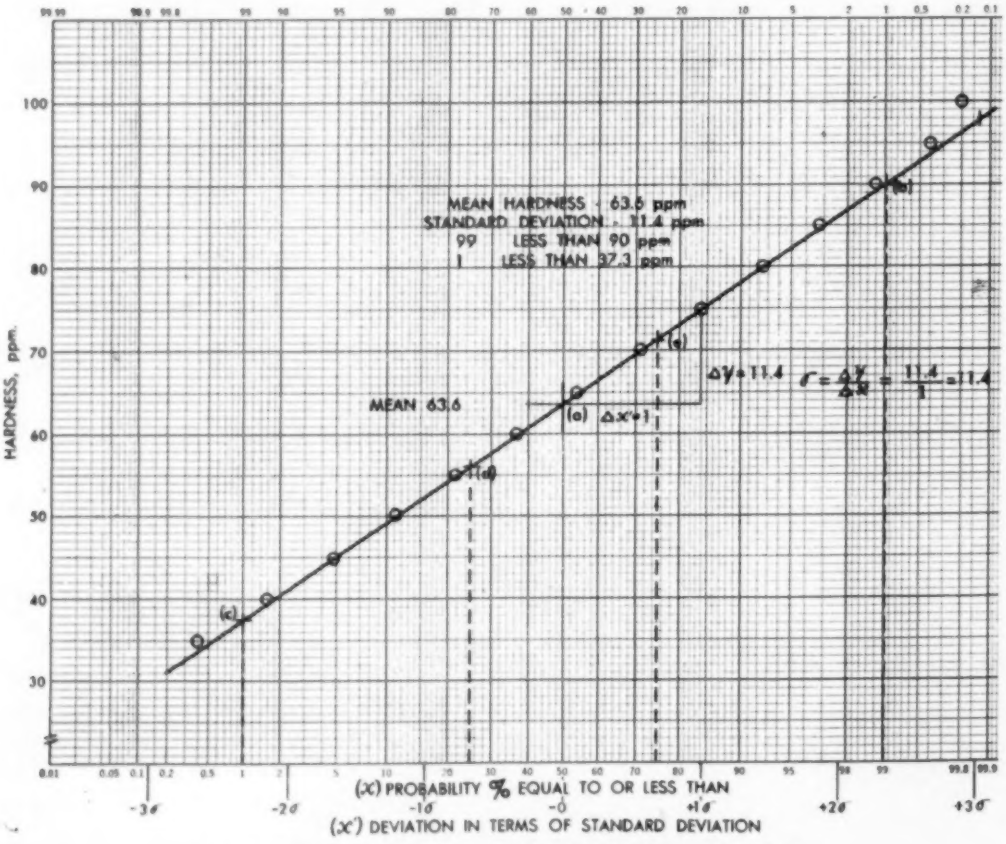


Fig. 7—Variation in Hardness in Softened Water Supply Based on 500 Determinations

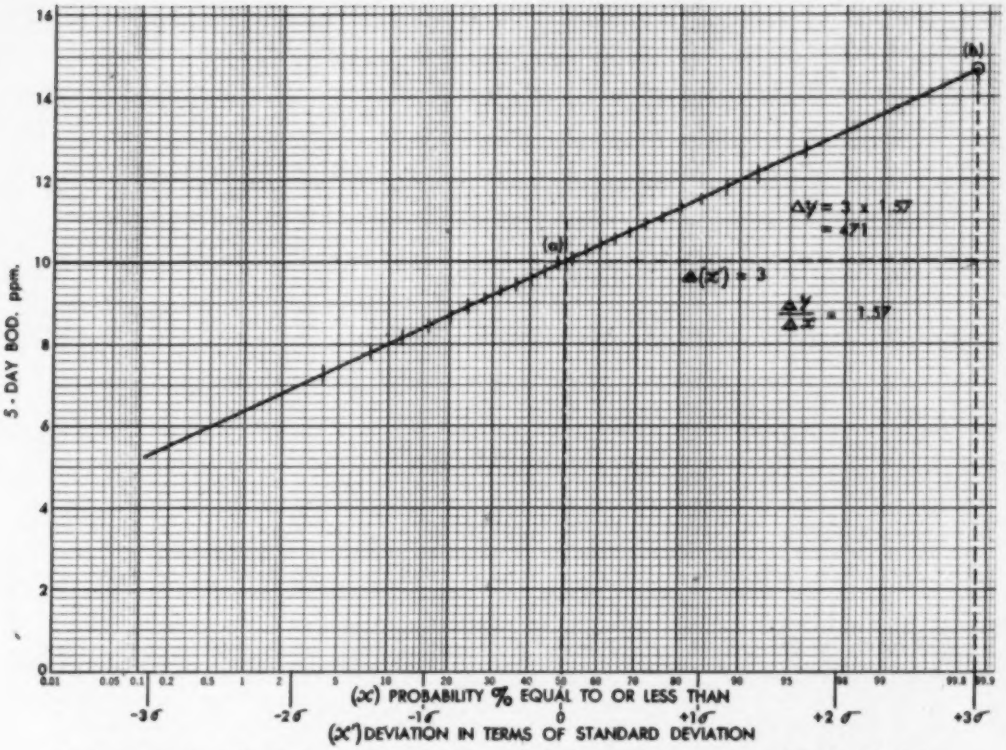


Fig. 8—Reproduction of Distribution of a Series of B.O.D. Determinations from Number, Mean, and Standard Deviations

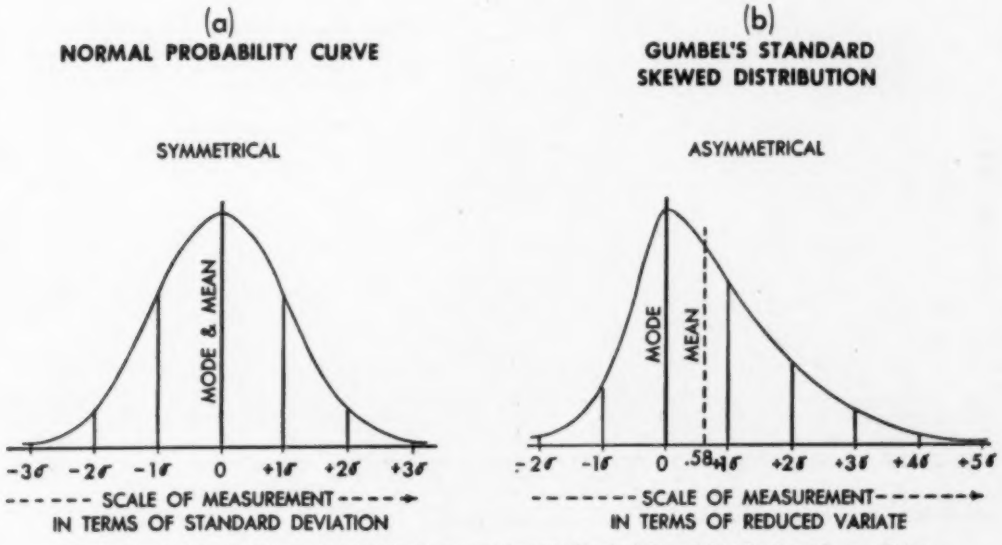


Fig. 9—Comparison of the Normal Probability Curve and Gumbel's Standard Skewed Distribution of Largest Values

Table 3

MAXIMUM ANNUAL FLOOD
Highest Peak Discharge In Each Water Year
Clark Fork Below Missoula, Mont.

Year	Discharge c.f.s.	Floods Arranged in order of Severity (Y)	Serial Number	Plotting Position (X)
(1)	(2)	(3)	(4)	(5)
1930	17,500	10,400	1	.0171
1931	12,200	11,700	2	.0879
1932	25,000	12,200	3	.1385
1933	36,800	14,200	4	.1892
1934	25,700	14,400	5	.2398
1935	20,200	17,500	6	.2904
1936	26,700	19,100	7	.3410
1937	11,700	19,700	8	.3917
1938	35,700	20,200	9	.4423
1939	22,000	22,000	10	.4929
1940	14,200	25,000	11	.5435
1941	10,400	25,700	12	.5941
1942	36,500	26,700	13	.6448
1943	33,200	30,500	14	.6954
1944	14,400	33,200	15	.7460
1945	19,100	35,700	16	.7966
1946	19,700	36,800	17	.8473
1947	45,900	45,900	18	.8979
1948	52,800	52,800	19	.9485

and for convenience may be read directly from Fig. 11. Only slight difference in the straight line plot on the skewed probability paper results between plotting positions determined from $m/(n+1)$ or from Gumbel's refinement, except with a small number of observations.

Plotting Series of Extreme Values

In summary, the procedure for plotting series of extreme values, maximum or minimum, on skewed probability paper is as follows:

1. Arrange the data in order of severity commencing with the least severe.
2. Assign a serial number "m" to each of the n values, 1, 2, 3, . . . n.
3. Compute the plotting position of each serial value, giving the probability equal to less severe than, for each value either by $m/(n+1)$ or by Gumbel's refinement.
4. Plot the points. The scale by which the observed measurements were made is laid off on the linear Y-axis; the computed plotting positions are the probability summation scale on the X-axis.
5. If a straight line is indicated by the plotted points it may be sketched graphically or it may be fitted by more precise means. Usually a graphical sketching is adequate.

The procedure and interpretations are best illustrated by specific applications which follow.

Flood Data

For purposes of illustrating a series of maximum values, the annual flood,* the highest peak discharge in each water year, is used. Table 3 represents such a series for Clark Fork below Missoula, Mont., drainage area 8,690 square miles, for the period 1930-1948. The plotting positions of Column 5 are in accordance with Gumbel's refinement obtained as follows:

Position of the most severe flood obtained from most severe curve, Fig. 11	.9485
Position for the least severe flood read from least severe curve, Fig. 11	.0373
Interval between least severe and most severe	.9112
Increment for successive points $\frac{.9112}{(19-1)}$	.050622

*Annual one-day flood, largest 24-hour average discharge among 365 days of each year, also develops a series of maximum values.

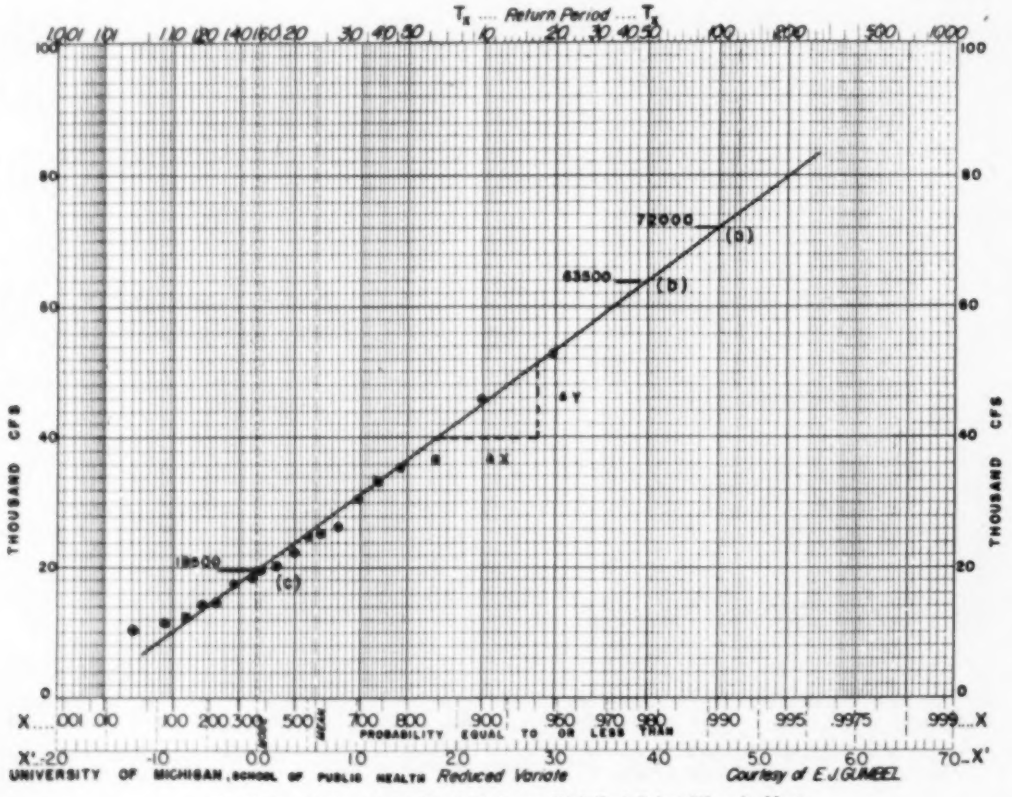

T_R .... Return Period .... T_R
1.001 1.01 1.10 1.20 1.40 1.60 2 3 4 5 10 20 30 40 50 100 200 500 1000
THOUSAND CFS
72000 (b)
63500 (b)
19500 (c)
Δ Y
Δ X
X ... .001 .01 .1 .2 .3 .5 .7 .8 .9 .95 .98 .99 .995 .9975 .999 ... X
PROBABILITY EQUAL TO OR LESS THAN
X' -20 -10 0 10 20 30 40 50 60 70 - X'
UNIVERSITY OF MICHIGAN, SCHOOL OF PUBLIC HEALTH
Reduced Variate
Courtesy of E. J. GUMBEL

Fig. 10—Probability Annual Flood Discharge Clark Fork Below Missoula, Mont.

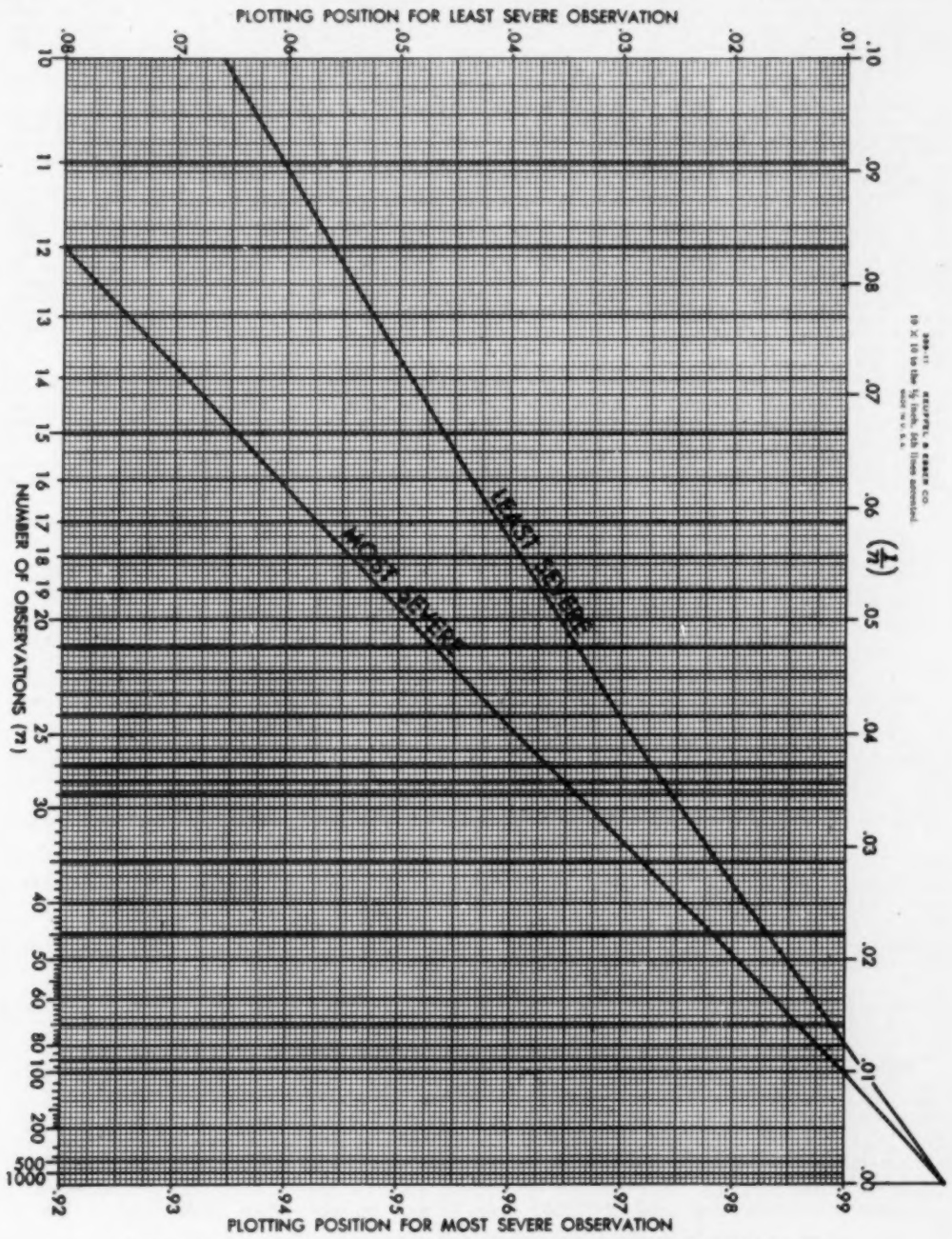

PLOTTING POSITION FOR LEAST SEVERE OBSERVATION
.08 .07 .06 .05 .04 .03 .02 .01 .10
.09 .08 .07 .06 (1/T) .05 .04 .03 .02 .01 .00
10 11 12 13 14 15 16 17 18 19 20 25 30 40 50 60 80 100 200 500 1000
NUMBER OF OBSERVATIONS (T)
LEAST SEVERE
MOST SEVERE
.92 .93 .94 .95 .96 .97 .98 .99
PLOTTING POSITION FOR MOST SEVERE OBSERVATION

Fig. 11—Plotting Positions for the Least Severe and the Most Severe of any Number of Observations for a Series of Either Maximum or Minimum Data (According to Gumbel)

Thus the position of the least severe flood is at .0373, the second least severe flood at (.0373 + .0506) or .0879, the third least severe at (.0879 + .0506) or .1385, etc., adding .0506 for each successive value until the 19th or most severe value is reached with a plotting position .9485.

Column 3 and Column 5 of Table 3 provide the coordinates for plotting the data on skewed probability paper as shown on Fig. 10. A straight line is indicated as represented by the solid line fitted through the data. Thus, the 19-year record, while short, is in accord with the theory of extreme values and the fitted line may be accepted as a representative sample of flood expectancy for this river and probability of flood severity may be read directly from the line extrapolated beyond the record.

Since the mean return period interval between observations is a year, it is customary to speak of flood severity as equaled or exceeded in the long-run on the average once in 100 years as the 100-year flood. For the Clark Fork the 100-year flood is located by extending vertically from 100 on the T_r scale to intersect the distribution line at (a), reading on the Y-scale 72,000 cfs. Similarly, in the long-run on the average once in 50 years a flood of 63,500 cfs. or greater may be expected, located at (b). The most probable flood value expected in any year is located where the mode cuts the distribution line, in this instance at (c) as 19,500 cfs.

Table 4

MINIMUM MONTHLY AVERAGE DROUGHT
Summer-Fall Period, May Through November, Ocmulgee River at Macon, Ga.

CFS. Per Sq. Mi. in order of Magnitude (Y) (1)	Serial Number (2)	Plotting Position (X) (3)
.954	1	.0373
.650	2	.0879
.485	3	.1385
.447	4	.1892
.446	5	.2398
.412	6	.2904
.412	7	.3410
.380	8	.3917
.377	9	.4423
.374	10	.4929
.360	11	.5435
.340	12	.5941
.335	13	.6448
.314	14	.6954
.298	15	.7460
.264	16	.7966
.228	17	.8473
.218	18	.8979
.114	19	.9485

The slope of the line on skewed probability paper is a measure of the degree of variation among the annual flood values. This slope may be obtained graphically by scaling any $\frac{\Delta Y}{\Delta X'}$ developed by the distribution line, employing the reduced variate scale for $\Delta X'$. If the flood flows are expressed in yields, cfs. per square mile of tributary drainage area, slopes for flood distributions for different drainage areas are directly comparable. In this example $\frac{\Delta Y}{\Delta X'}$ 11,400 in terms of cfs., or 1.31 in terms of yield. In a similar manner, if the Most Probable Flood (located by the Mode, $X'=O$) is also expressed as a yield, cfs. per square mile of tributary drainage area (in this example 19,500/8,690 or 2.245), a comparative measure of flood potential is obtained. The slope and the Most Probable Flood (MPF) expressed in terms of yield are two significant indices for comparative study of flood characteristics. These indices also afford an excellent summary, as the complete distribution line can be reconstructed simply by locating the MPF on the modal line and from this point lay off the slope and draw the distribution line.

Drought Data

For purposes of developing a series of minimum values, minimum monthly* average drought flows occurring during the summer-fall period, May through November, of each year have been selected from

*Minimum daily average or minimum weekly average discharge data also develop series of minimum extreme values.

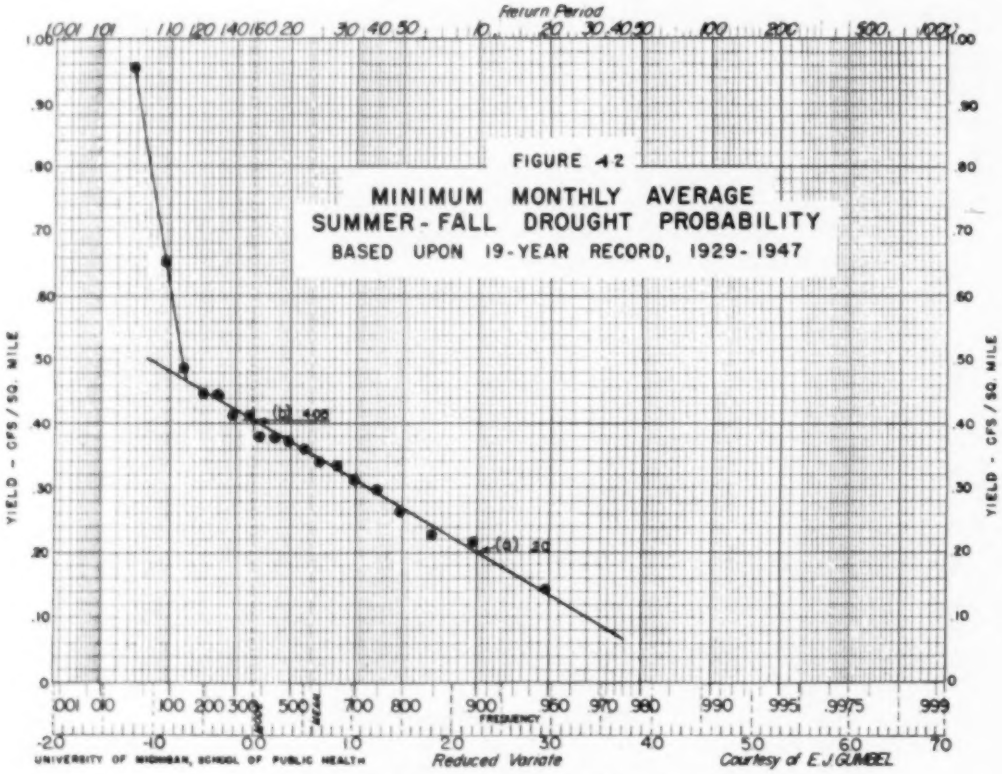

Return Period
1.001 1.01 1.10 1.20 1.40 1.60 2.0 3.0 4.0 5.0 10. 20. 30. 40. 50. 100. 200. 500. 1000.
FIGURE 42
MINIMUM MONTHLY AVERAGE
SUMMER-FALL DROUGHT PROBABILITY
BASED UPON 19-YEAR RECORD, 1929-1947
YIELD - CFS/SQ. MILE
(b) 4.08
(c) 2.0
.001 .010 .100 .200 .300 .500 .700 .800 .900 .950 .970 .980 .990 .995 .9975 .999
FREQUENCY
-20 -10 0.0 10 20 30 40 50 60 70
Reduced Variate
UNIVERSITY OF MICHIGAN, SCHOOL OF PUBLIC HEALTH
Courtesy of E. J. GUMBEL

Fig. 12—Minimum Monthly Average Summer-Fall Drought Probability (Based upon 19-year record, 1929-47.)

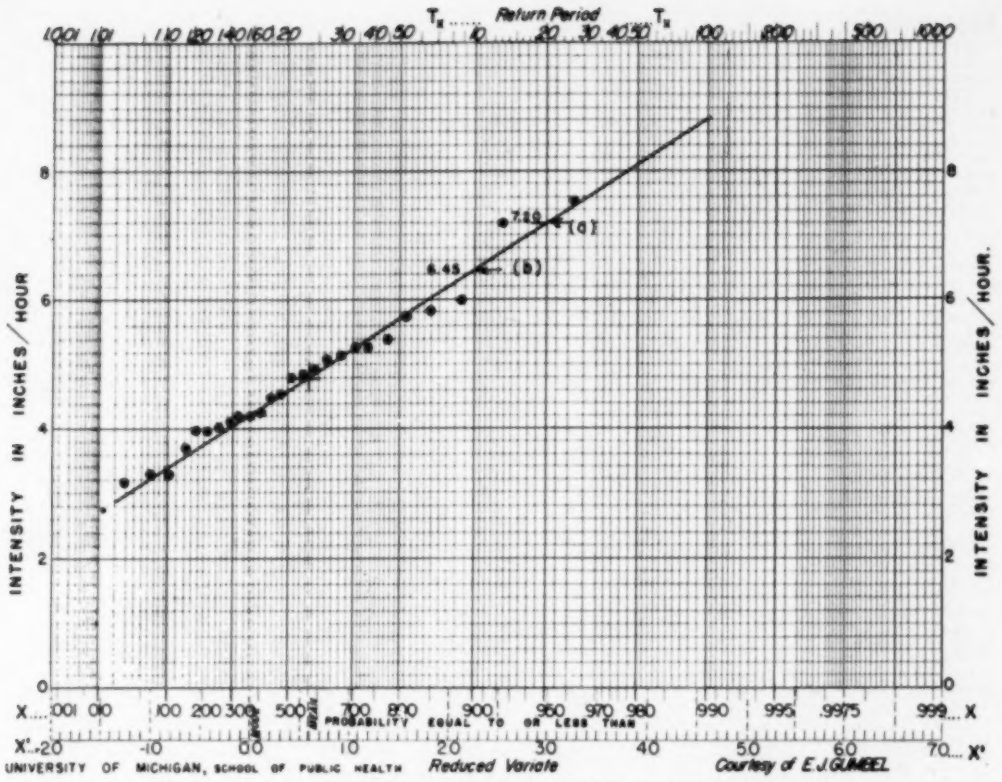


Fig. 13—Probability Maximum Storm Rainfall Intensity for 10 Minute Duration, New York City

the runoff records of the Ocmulgee River at Macon, Ga. (drainage area 2,240 square miles) as shown in Table 4. In this illustration, runoff is expressed as yield, cfs. per square mile. The plotting positions in Column 3 are in accord with Gumbel's refinement and are obtained in the same manner as previously illustrated for floods. Using as coordinates the minimum monthly drought flows of Column 1 and corresponding plotting positions in Column 3 the droughts are plotted as shown in Fig. 12.

Table 5
MAXIMUM STORM RAINFALL INTENSITY FOR 10 MINUTE DURATION
NEW YORK CITY

Year	10 Min. Duration		Serial Number	Plotting Position (X)
	Inches/Hr.	In order of Magnitude (Y)		
(1)	(2)	(3)	(4)	(5)
1895	3.96	3.18	1	0.0282
1896	5.10	3.30	2	.0656
1897	3.72	3.30	3	.1029
1898	3.18	3.72	4	.1403
1899	4.20	3.96	5	.1777
1900	3.30	3.96	6	.2150
1901	4.92	4.02	7	.2524
1902	5.16	4.14	8	.2897
1903	4.14	4.20	9	.3271
1904	4.86	4.20	10	.3645
1905	7.56	4.26	11	.4018
1906	5.82	4.50	12	.4392
1907	3.96	4.56	13	.4766
1908	3.30	4.80	14	.5139
1909	5.28	4.86	15	.5513
1910	6.00	4.92	16	.5887
1911	4.56	5.10	17	.6260
1912	5.28	5.16	18	.6634
1913	7.20	5.28	19	.7008
1914	4.80	5.28	20	.7381
1915	5.40	5.40	21	.7755
1916	4.50	5.76	22	.8128
1917	5.76	5.82	23	.8502
1918	4.02	6.00	24	.8876
1919	4.20	7.20	25	.9249
1920	4.26	7.56	26	.9623

Since data are arranged in order of severity, it will be noted that the distribution slopes downward. Another characteristic of drought distributions commonly encountered is the sharp break in the distribution line taking place at the left of the mode. Such a break formed by the less severe values to the left of the mode may be regarded as defining when the flow is no longer a drought and is blending back into the normal runoff. Our interest lies in the distribution of the true droughts to the right of the mode and it is to this portion of the data that a straight line is sketched or fitted. For this particular record a straight line for the more severe droughts is clearly indicated, from which probability of any drought severity may be determined. The most probable drought is located at (b) as .405 cfs. per square mile. A drought flow expected in the long run on the average once in 10 years is located at (a) as .20 cfs. per square mile. Droughts for any other return period may be read from the distribution line in a similar manner.

The slope of the distribution is readily obtained graphically by scaling $\frac{\Delta Y}{\Delta X'}$ or 0.092.

Storm Rainfall Intensity

A good example of a series of maximum values is the maximum rainfall intensity as an average for a given duration period occurring at the center of the worst storm each year in a localized geographical region. Table 5 represents such a series of data for 26 years from 11 rain gaging station in New York City, selecting the maximum intensity for a 10 minute duration. The plotting positions (Column 5) for the 26 values, again, are in accord with Gumbel's refinement as illustrated for floods. The series plots as a straight line throughout, as shown on Figure 13. From the distribution line the probability of any intensity can be determined. Thus on the average in the long run an intensity, as an average for 10 minute duration, of 7.20 inches per hour or greater may be expected once in 20 years, located at (a); and 6.45 inches per hour once in 10 years. Intensities for other duration periods form similar straight line distributions, and from them a rational set of storm rainfall intensity curves can readily be constructed to serve as a basis for storm water drainage design.

Water Supply Storage

Fig. 14 illustrates an application of skewed probability paper to a storage problem. The maximum annual storage required each year to meet a demand of 500 mgd. was taken from a mass curve of net run-off from the Schoharie-Esopus basin for the period 1903-1945. Since drought severity is reflected in magnitude of storage required, the storage values are arranged in ascending order of magnitude, as shown in Table 6. Plotting positions for the 43 values are in accord with Gumbel's refinement and are obtained in the same manner as illustrated for floods. The storage values associated with true droughts are those points located to the right of the mode and the distribution line should be sketched or fitted through these values. The small storages associated with the less severe droughts to the left of the mode usually fall below the distribution line. The probability of any storage requirement to insure a water supply demand of 500 mgd. can be read directly from the distribution line. Thus, to protect against drought severity expected on the average in the long run once in 50 years, it would be necessary to provide storage of 100 billion gallons, located at (a) on Figure 14. This would provide storage sufficient to meet demand on 98 per cent of the years. Similarly, for drought severity expected once in 20 years the storage required would be 85 billion gallons, located at (b), providing for 95 per cent of the years.

In some storage situations the demand is set so high that reservoirs do not refill on the average each year. Under these conditions the unit of time may become 2 or 3 years and one maximum storage is selected from the mass curve for each such interval. Data are handled in the same manner except that the return period is in the new unit of time and is no longer directly in years.

IV—Evaluation of Bacterial Density

This section will deal with logarithmic probability paper as applied to the evaluation of bacterial density. Certain types of data such as bacterial density determined by the decimal dilution method, are logarithmically normal. Such a distribution will plot as a straight line on normal probability paper previously described providing the logarithms of the measurements are substituted for the original data. Log-probability paper avoids converting the data to logarithms by employing a logarithmic grid as the ordinate scale. The original data may then be plotted directly on the log-grid.

Table 6

WATER SUPPLY STORAGE REQUIREMENTS FOR A DEMAND OF 500 MGD. Based Upon Mass Curve of Net Yield Schoharie-Esopus Drainage Basin, 671 Sq. Mi.

Year (1)	Storage Required Billion Gallons (2)	In order of Magnitude (Y) (3)	Serial Number (4)	Plotting Position (X) (5)
1903	3	4	1	.0177
1904	32	5	2	.0405
1905	52	8	3	.0635
1906	40	9	4	.0861
1907	27	9	5	.1089
1908	60	14	6	.1317
1909	67	20	7	.1545
1910	58	21	8	.1773
1911	32	21	9	.2001
1912	40	27	10	.2229
1913	47	28	11	.2457
1914	76	28	12	.2685
1915	14	29	13	.2913
1916	21	32	14	.3141
1917	29	32	15	.3369
1918	49	33	16	.3597
1919	9	36	17	.3825
1920	21	39	18	.4053
1921	55	40	19	.4281
1922	60	40	20	.4509
1923	40	40	21	.4737
1924	33	45	22	.4965
1925	50	46	23	.5193
1926	50	47	24	.5421
1927	20	48	25	.5649
1928	45	49	26	.5877
1929	48	49	27	.6105
1930	94	50	28	.6333
1931	60	50	29	.6561
1932	61	52	30	.6789
1933	28	55	31	.7017
1934	39	55	32	.7245
1935	36	58	33	.7473
1936	70	60	34	.7701
1937	9	60	35	.7929
1938	3	60	36	.8157
1939	94	61	37	.8385
1940	46	67	38	.8613
1941	71	70	39	.8841
1942	28	71	40	.908
1943	49	76	41	.9305
1944	55	94	42	.954
1945	4	94	43	.977

Fig. 15 illustrates a logarithmically normal distribution plotted on log-probability paper. The X and X' scales are identical with those previously described for normal probability paper; X-scale at the bottom is probability (in per cent) equal to or less than or probability of not exceeding, X'-scale at the top is deviation from the mean in terms of standard deviation. The left ordinate scale, Y, is a logarithmic grid assigned to the scale of measurement of the original data; Y'-scale at the right is a linear grid on which logarithms of the original data are located.

Table 7

16 SAMPLES TAKEN SIMULTANEOUSLY FROM THE SAME SOURCE 10 PORTIONS IN EACH OF 3 DECIMAL DILUTIONS

MPN per ml in order of Magnitude Millions	Serial Number m	Plotting Position m/(n+1) as %
2.88	1	5.9
3.29	2	11.8
3.29	3	17.6
3.34	4	23.5
3.99	5	29.4
3.99	6	35.3
4.74	7	41.2
4.74	8	47.0
4.93	9	52.9
4.93	10	58.3
5.89	11	64.6
6.22	12	70.5
6.22	13	76.5
7.00	14	82.3
7.42	15	88.2
9.33	16	94.1

Plotting on Log-Probability Paper

The procedure in plotting on log-probability paper is similar to that employed for normal probability paper:

(1) Arrange the data in order of ascending magnitude.

(2) Assign a serial number "m" to each of the n values, 1, 2, 3, ... n.

(3) Compute the plotting position of each serial value, giving the probability equal to or less than for each value by the expression $m/(n+1)$ expressing the ratio as a percentage.

(4) The units of measurement of the original data are laid off on the logarithmic grid* as the Y-axis and the plotting positions are the probability scale on the X-axis. The points are plotted using these (X, Y) coordinates. (Table 7 shows the coordinates for the 16 values plotted on Fig. 15.)

In interpreting a plot on log-probability paper it is cautioned that while the original data are plotted on the Y scale, actually it is the corresponding Y' values, the logarithms of the original data, that form the normal distribution. Hence the mean and the standard deviation are expressed in terms of logarithms. The subscript (Log)

*If more than two log cycles are needed, sheets of log-probability paper can be pasted together.

is employed to indicate that a logarithmically normal distribution is dealt with. The procedure for determining graphically the $\text{mean}_{(\text{Log})}$ and $\text{sigma}_{(\text{Log})}$ is identical with that described for normal probability paper except that Y' scale is employed. Referring to Fig. 15

$$\text{Mean}_{(\text{Log})} = 6.687$$

located on the Y' scale opposite (a) where 50 per cent cuts the distribution line. This is equivalent to the arithmetic mean of the logarithms of the original values.

The slope of the distribution line is the measure of variation of the data and provides the standard deviation in terms of logarithms.

$$\sigma_{(\text{Log})} = \frac{\Delta Y'}{\Delta X'} = .174$$

$\Delta Y'$ is measured on Y' scale and $\Delta X'$ is measured on the X' scale.

It is cautioned that in computing analytically ranges for any confidence it is essential first to deal in terms of logarithms. After the logarithms of the limits of any range are determined their anti-logs can be obtained and results expressed in terms of the original units of measurements. The advantage of log-probability paper is that these conversions are automatically accomplished. Again referring to Fig. 15, the $\text{mean}_{(\text{Log})}$ 6.687, is converted to units of the original measurement simply by reading directly on the Y scale, giving a value 4,860,000 per ml. Similarly the range for $\text{mean}_{(\text{Log})} \pm 2\sigma_{(\text{Log})}$ in terms of logarithms is

$$6.687 \pm 2 \times .174 \qquad (6.339 \text{ to } 7.035)$$

located by (b) and (c) where -2σ and $+2\sigma$ intersect the distribution line, reading on the Y' scale. The limits of this range converted to units of the original measurements are directly obtained by reading on the Y scale

(2,180,000 per ml to 10,820,000 per ml)*

Concepts of Mean Density and Distribution of Bacteria

It is first essential to introduce some basic concepts about bacterial density in a liquid medium. If it were possible to count the entire bacterial population in the entire water supply, the true *Mean Density* (M.D.) would be the total count divided by the total volume. If less than the total volume were employed in counting, it would be found that the densities in the samples would vary about the true Mean Density, the smaller samples showing greater variation than the larger samples. Perfect admixture would require exactly the same number of bacteria in each and every unit volume; complete segregation, on the other hand, would require all cells to be located in one single unit volume. Such extreme distributions of bacteria among unit volumes of water do not exist. The actual distribution is random and would tend toward an equilibrium condition between these extremes, governed by the laws of chance.

Inherently, therefore, we expect variation in results from small samples even if they are all drawn from the same supply at the same instant. Fortunately, the nature of these expected variations can be defined and series of test results can be reduced to reliable estimates of the true Mean Density as the basic measure of bacterial quality.

Nature of Variation of MPN's

Three fundamental characteristics of the nature of variation in MPN's determined from test results employing multiple portions in three decimal dilutions are:

(1) The distribution is logarithmically normal, that is, series of MPN's plot as a straight line on log-probability paper.

(2) The estimate of the true *Mean Density* is located at the midpoint of the distribution at 50 per cent.

(3) The slope of the distribution line depends upon the number of portions employed; small number of portions steep

*Note, that the deviations in terms of the original units of measure (Y) are not equal about the mean; $2\sigma_{(\text{Log})}$ plus $\text{mean}_{(\text{Log})}$ produces a Y of 10,820,000 or 5,960,000 above the mean of 4,860,000 while $2\sigma_{(\text{Log})}$ minus $\text{mean}_{(\text{Log})}$ produces a Y of 2,180,000 only 2,680,000 below the mean. This is inherent in the skew of the *logarithmically* normal distribution.

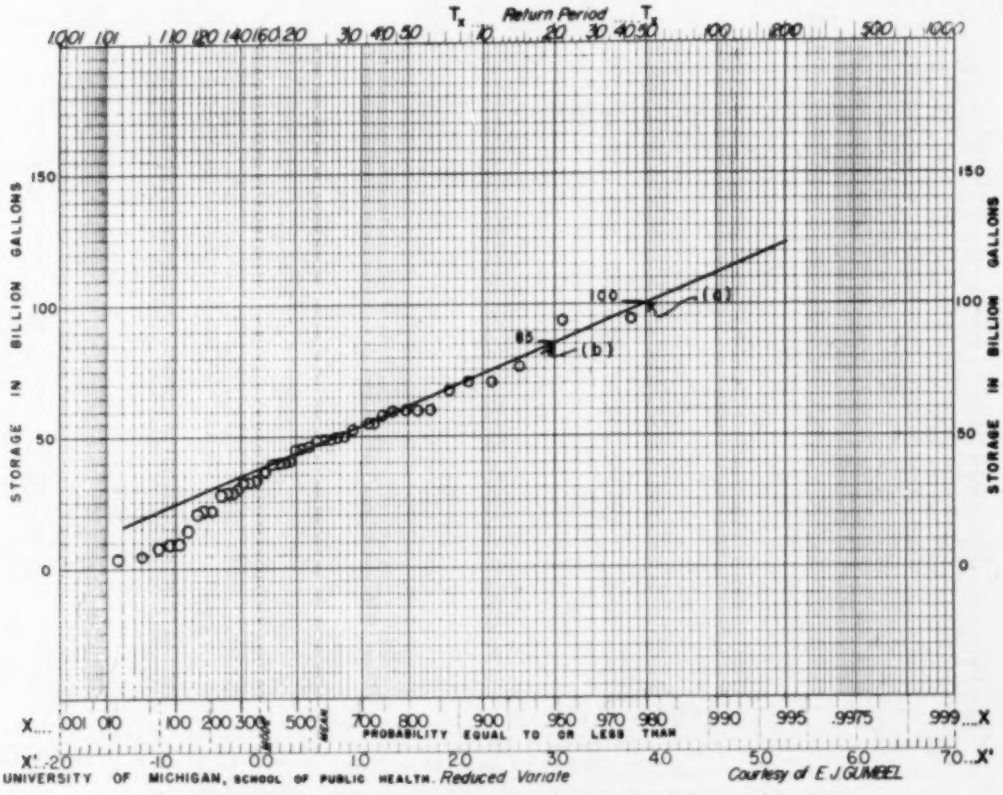

T_x Return Period T_x
1.001 1.01 1.10 1.20 1.40 1.60 2.0 3.0 4.0 5.0 10 20 30 40 50 100 200 500 1000
STORAGE IN BILLION GALLONS
150
100
50
0
(a)
(b)
(c)
X .001 .01 .100 200 300 500 700 800 900 950 970 980 990 995 .9975 .999 X
PROBABILITY EQUAL TO OR LESS THAN
X' -2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 X'
Reduced Variate
UNIVERSITY OF MICHIGAN, SCHOOL OF PUBLIC HEALTH
Courtesy of E.J.GUMBEL

Fig. 14—Probability Maximum Storage Requirements for Water Supply Demand of 500 MGD. (Schoharie-Esopus Basin, 671 sq. mi.)

slope, wide variation; large number of portions flat slope, narrow variation.

These characteristics can be developed mathematically [1] and verified experimentally.

Figure 16 shows the results of theoretical probability distribution of possible results from *20 portions* in each of 3 decimal dilutions with a known true Mean Density of 1.5 bacteria per ml. Note:

(1) Almost a perfect straight line develops.

(2) The distribution line cuts 50 per cent at a density of 1.5 which is equal to the theoretical true Mean Density employed.

(3) The slope is relatively flat, with $\sigma_{(Log)} = 0.1227$.

Figure 17, likewise, shows the results of theoretical probability distribution of possible results with the same true Mean Density 1.5, but employing only *5 portions* in each of 3 decimal dilutions. Note again:

(1) A straight line develops.

(2) The distribution line cuts 50 per cent at the theoretical true Mean Density of 1.5.

(3) The slope is steeper with

$$\sigma_{(Log)} = 0.2434$$

More generally $\sigma_{(Log)}$, the slope, is related to the number of portions (n) as

$$\sigma_{(Log)} = \frac{.3487}{\sqrt{n}}$$

Graphically, the slope ($\sigma_{(Log)}$) for various values of (n), number of portions, is shown in Fig. 18. These are the standard distribution slopes expected purely by virtue of the test procedure, depending solely on the number of *portions* employed. All the distribution lines arise from water of the same Mean Density but the variation of individual MPN values can be expected to be greater and greater as the number of portions is decreased.

Hence to know the reliability of an MPN it is essential to know the number of *portions* employed in the test procedure.

These relationships can be verified experimentally by taking a set of samples simultaneously from the same source, thus insuring a constant Mean Density for all samples. Fig. 15, previously referred to, represents the distribution of MPN values for 16 samples taken from a controlled source in such a manner, each sample composed of *10 portions* in each of 3 decimal dilutions.

The slope of the line described by the plotted points is in remarkable agreement with the theoretical or standard slope expected when 10 portions are employed, namely $\sigma_{(Log)} = 0.1735$. As the number of samples increases the experimental slope approaches the theoretical standard slope as a limit. This holds of course only if there is no change in the true Mean Density during the period when samples are drawn.

Figure 19 is the distribution of MPN's of a set of 16 samples taken simultaneously from a raw water supply, employing *3 portions* in each of 3 decimal dilutions. When only 3 portions in each of 3 decimal dilutions are employed the number of possible outcomes is less and the distribution is less continuous in character, but the points describe a line in close agreement with the theoretical or standard slope expected for *3 portions*, namely, $\sigma_{(Log)} = 0.32$.

If samples are taken over a time interval, such as daily routine samples over a period of a month, true Mean Density undoubtedly would not remain constant and hence the daily MPN's would be drawn from water of changing quality. Under these conditions of changing quality, the distribution line described by the individual MPN's will be steeper than that where

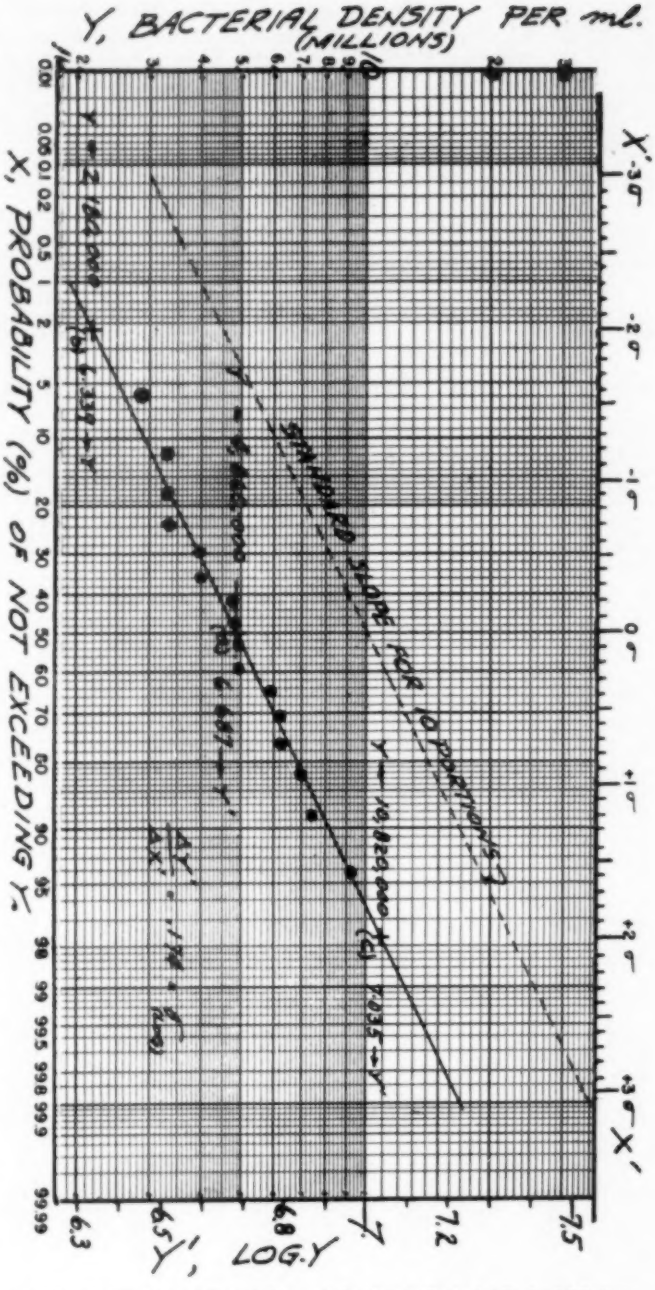


Fig. 15—Verification of Standard Slope—10 Portions in Each of 3 Decimal Dilutions

(1) *Proceedings Inservice Training Course in Sewage and Industrial Waste Disposal*, 1949, School of Public Health, University of Michigan.

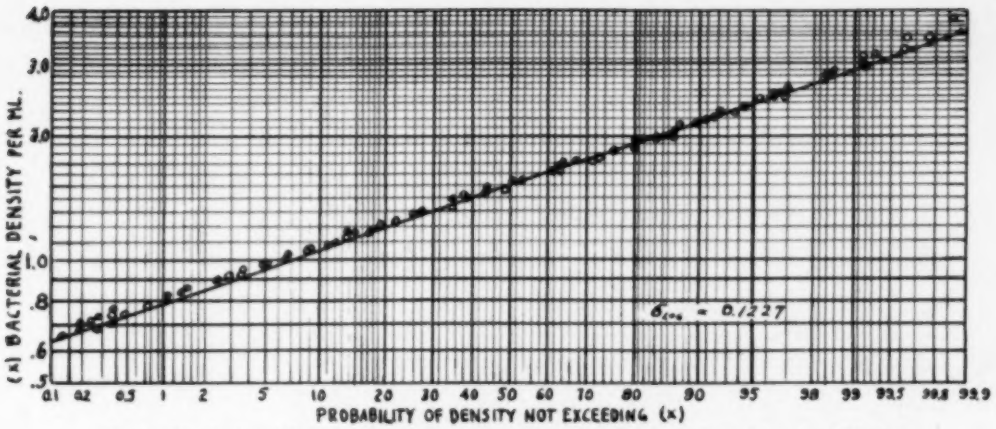


Fig. 16—Distribution of Bacterial Density Expected for Sample of 20 Portions Each of 3 Decimal Dilutions at True Mean Density of 1.5 per ml.

quality remained constant. Hence the comparison of the actual slope with that expected for the number of portions employed indicates at once if quality remained stable or was subject to real changes in level of Mean Density during the sampling period. A graphical method for determining the extent of such a change in Mean Density is illustrated in the following examples.

Evaluation of Raw Water Supply Data

Figure 20 represents the application of log-probability paper to evaluation of coliform density of the raw water supply for the City of Wyandotte, Mich.,* based upon daily routine samples of 3 portions in each of 3 decimal dilutions for the 71 day period July 22 to Sept. 30, 1950. A reasonably straight line distribution is described by the distribution of the 71 MPN values shown as heavy dots.

THE MEAN DENSITY—The graphical line "A" through the data cuts 50 per cent at $Mean_{(Log)}$ of 4.447 (read on Y'-scale or a

*Data courtesy George Hazey.

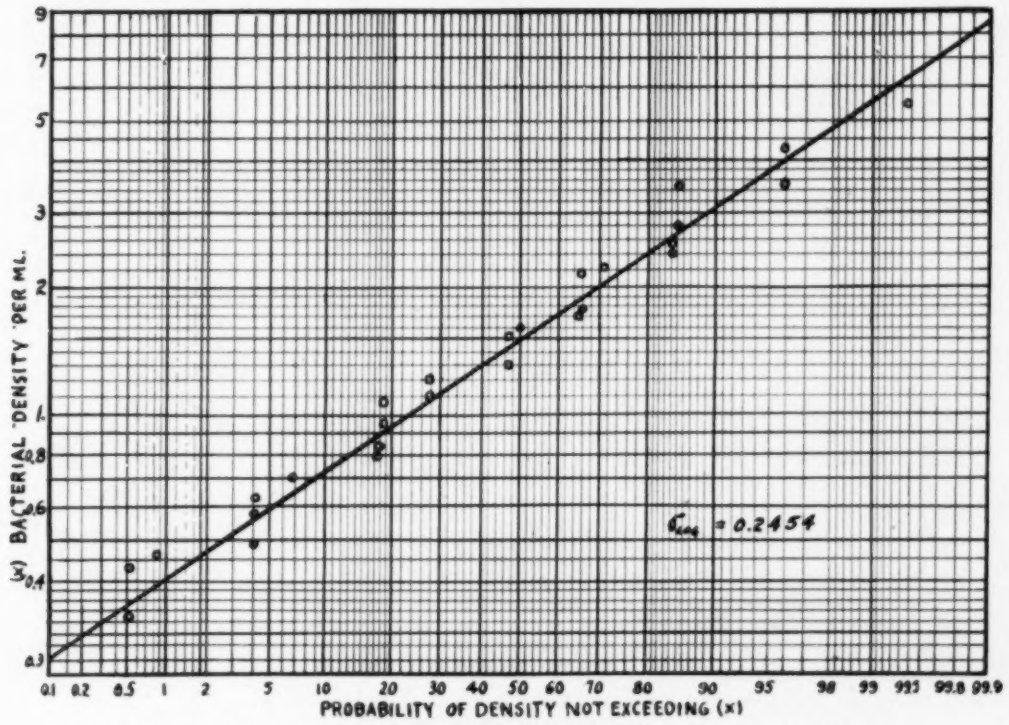


Fig. 17—Distribution of Bacterial Density Expected for Sample of 5 Portions Each of 3 Decimal Dilutions at True Mean Density of 1.5 per ml.

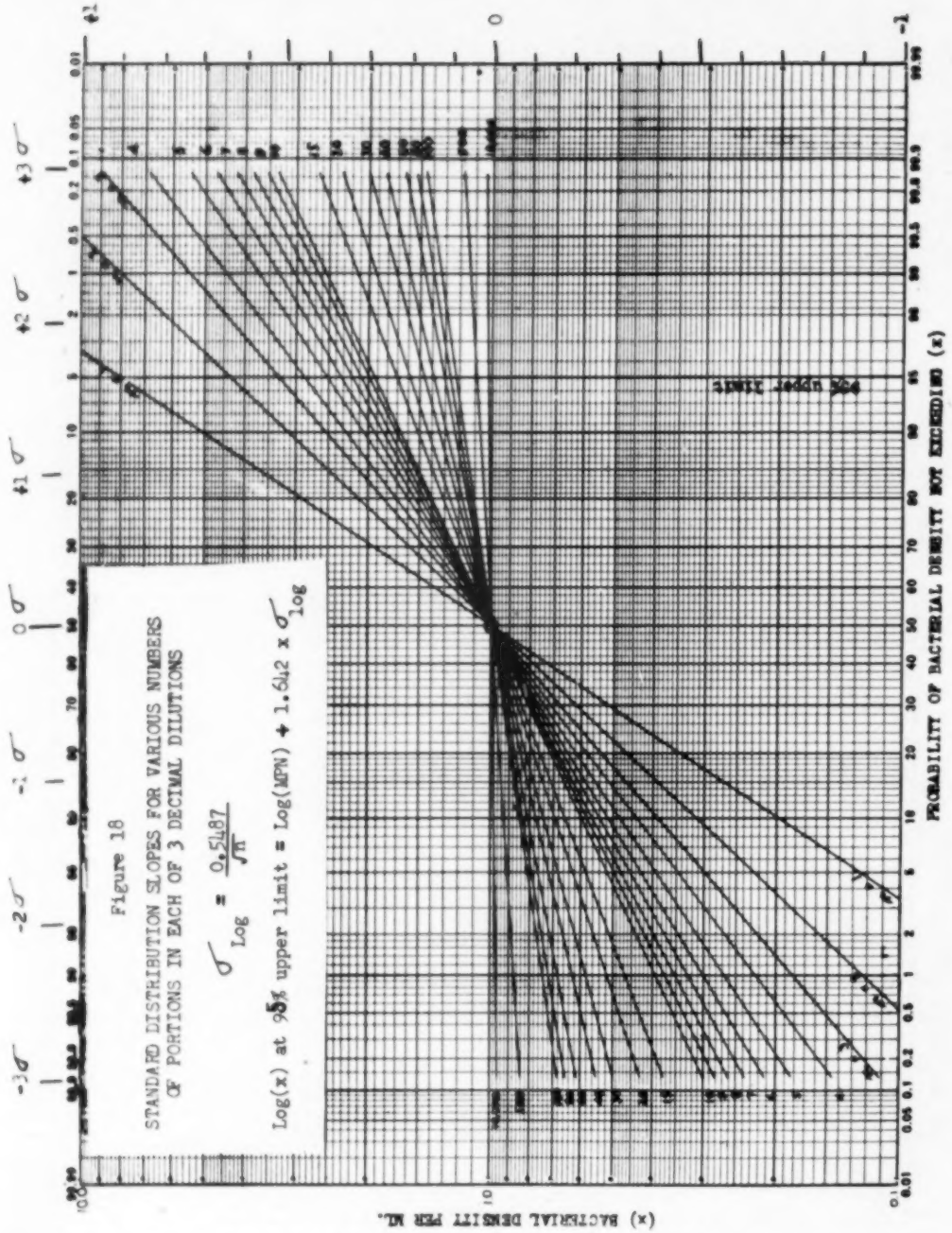


Figure 18
STANDARD DISTRIBUTION SLOPES FOR VARIOUS NUMBERS OF PORTIONS IN EACH OF 3 DECIMAL DILUTIONS
$\sigma_{Log} = \frac{0.5487}{\sqrt{n}}$
Log(x) at 95% upper limit = Log(MPN) + 1.642 x σ_{log}
95% upper limit
PROBABILITY OF BACTERIAL DENSITY NOT EXCEEDING (x)
(x) BACTERIAL DENSITY PER ML.

Fig. 18—Standard Distribution Slopes for Various Numbers of Portions in Each of 3 Decimal Dilutions

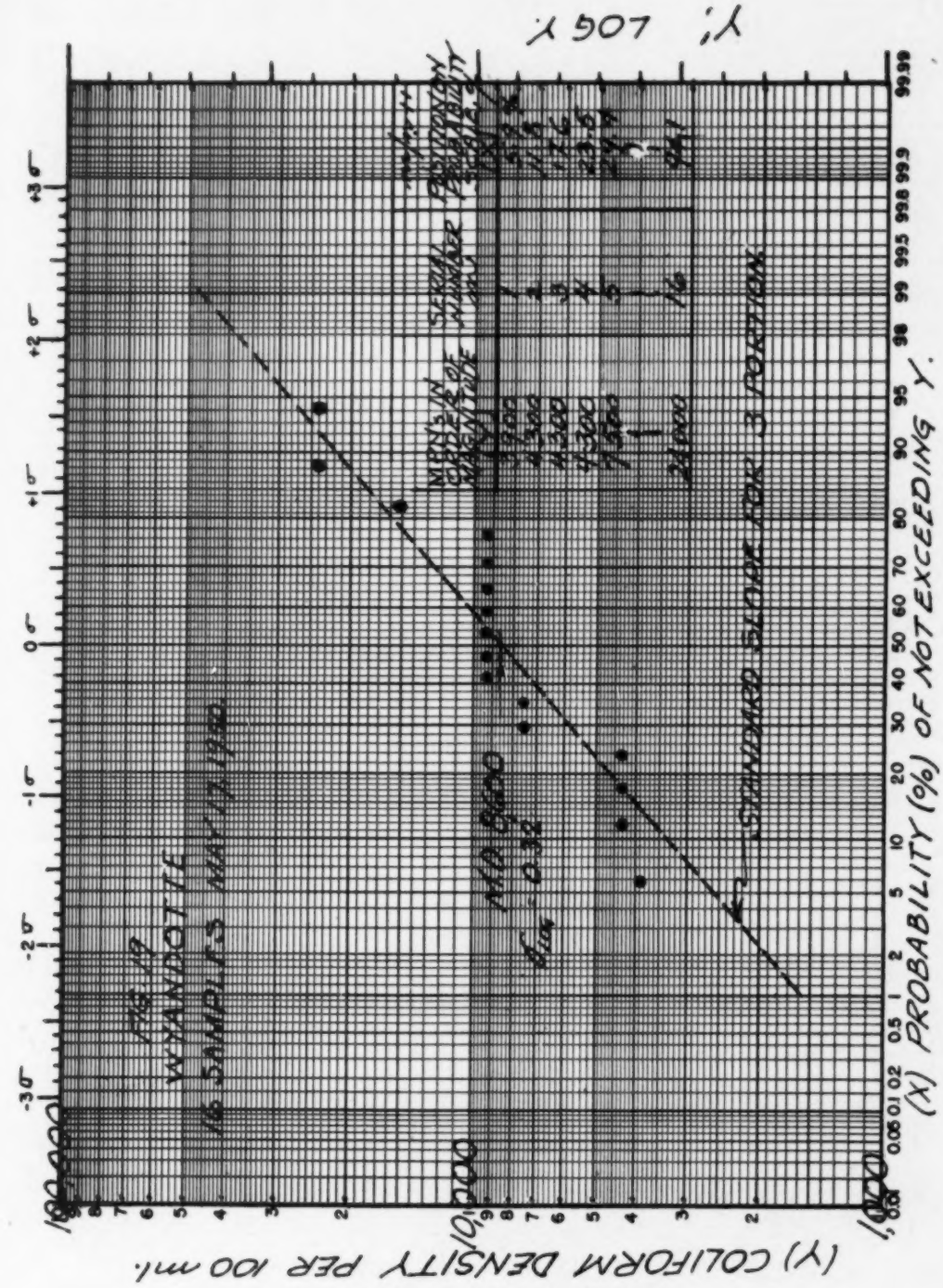


Fig. 19—Wyandotte, Mich.—16 Samples May 17, 1950

Mean Density of 28,000 coliform per 100 ml (read on Y-scale).

THE SLOPE, $\sigma_{(Log)}$—The slope of the distribution line "A" determines $\sigma_{(Log)}$ which is given by scaling $\Delta Y'$ for a unit $\Delta X'$ in this example

$$\sigma_{(Log)} = .49$$

MEASURE OF STABILITY OR CHANGE IN MEAN DENSITY—The slope expected for a *3 portion* test procedure as transferred from the standard slopes of Fig. 18, is indicated on Fig. 20 as the dotted line "B". The actual distribution line "A" is steeper than that expected for a 3 portion test procedure which indicates at once that changes in level of Mean Density, and therefore real changes in quality, took place during the sampling period.

The question now arises: Within what range did the level of Mean Density shift? The answer to this depends upon a confidence we wish to have in the range defined. A range for a 90 per cent confidence would have a lower limit not exceeding 5 per cent and an upper limit not exceeding 95 per cent. Such a range in Mean Density is readily located graphically by projecting parallel to the standard slope line "B" from the intersections of 5 and 95 per cent with the distribution line "A". Probability of 5 per cent intersects line "A" at (a) (4,400); projecting parallel to line "B" to probability of 50 per cent locates the lower limit of Mean Density at (w) (14,500).

Similarly, probability 95 per cent intersects line "A" at (b) (175,000); projecting parallel to line "B" to probability 50 per cent locates the upper limit of Mean Density at (z) (52,500). This is to say that if 5 per cent of the MPN values do not exceed 4,400, (a), and the quality of water remained stable during sampling, the distribution line would fall along (a) (w) and would define a Mean Density of 14,500 located by (w).

Similarly if 95 per cent of the MPN values did not exceed 175,000, (b), and quality remained stable the distribution line would fall along (b) (z) and would define a Mean Density of 52,500 at (z). From this it is then reasoned that the probability is 5 per cent, that Mean Density was equal to or less than 14,500 and the probability is 5 per cent that Mean Density was equal to or greater than 52,500; or the probability is 90 per cent that Mean Density varied within the range 14,500 to 52,500, between (w) and (z).

In a similar manner the range for any confidence can be defined. We are 50 per cent confident that the Mean Density varied within the range 21,000 to 36,000; or 98

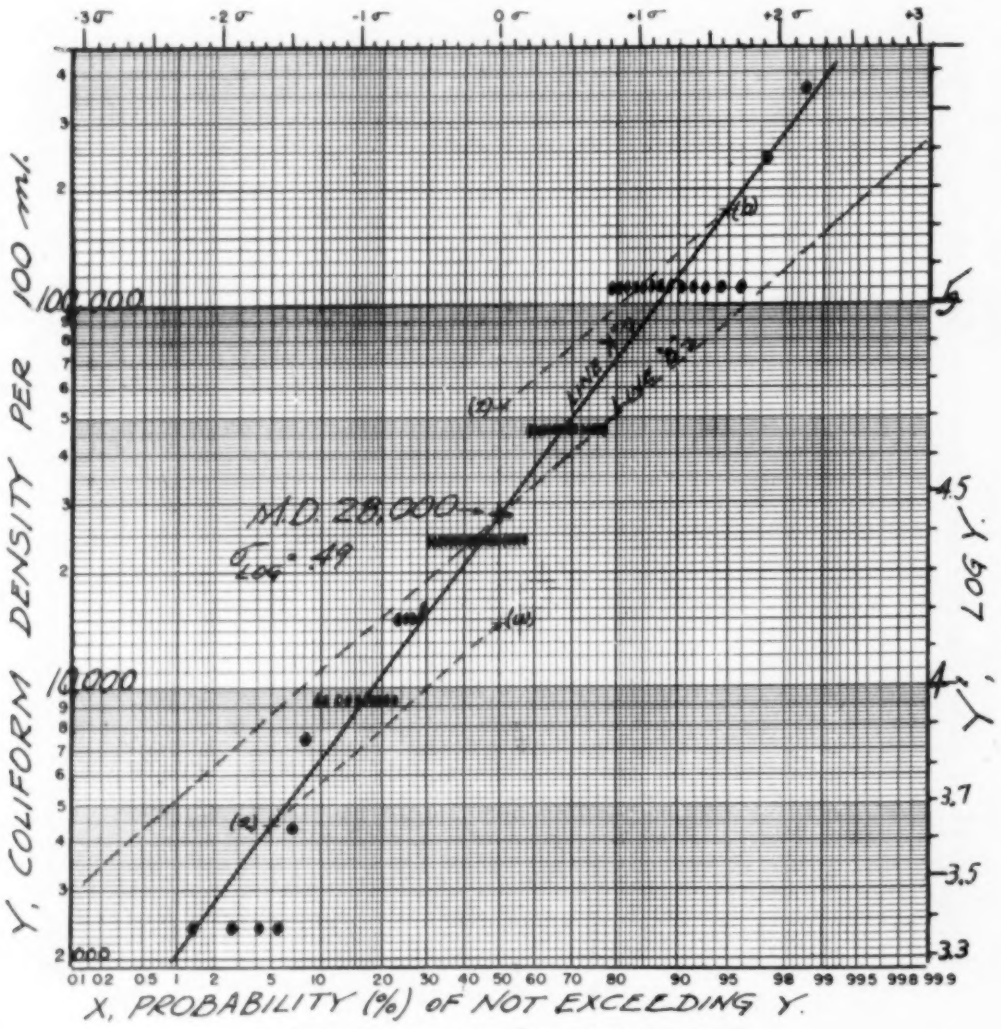


Fig. 20—Wyandotte, Mich.—New Intake—July 22 to Sept. 30, 1950

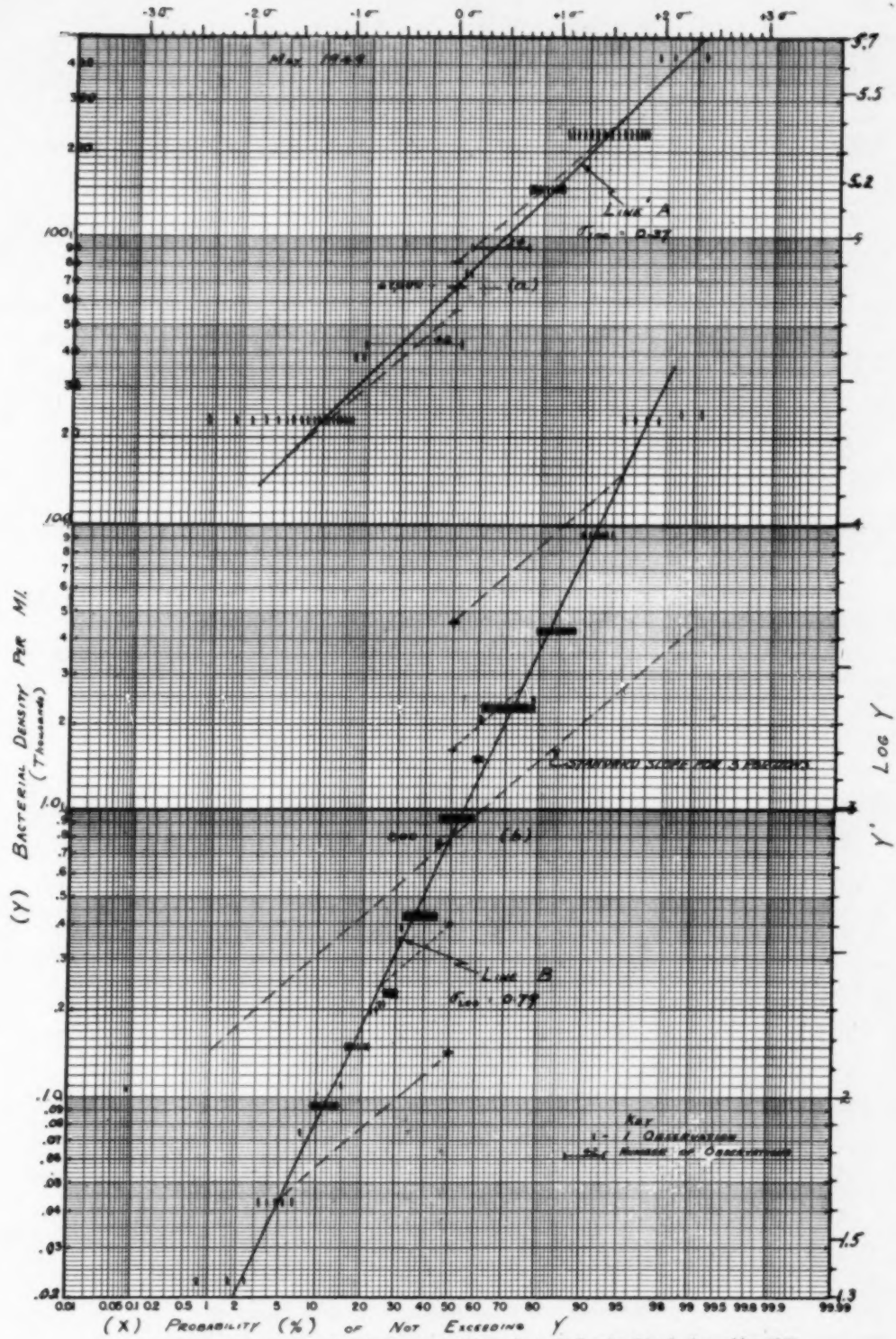


Fig. 21—Buffalo, N.Y., Sewage Plant Influent and Effluent Bacterial Density Distributions—May 1949

per cent confident that it varied within the range 11,000 to 70,000.

Since samples were taken at daily intervals, it can be reasoned that:

50 per cent of the days the Mean Density was above or below 28,000

50 per cent of the days the Mean Density was within the range 21,000 to 36,000

90 per cent of the days the Mean Density was within the range 14,500 to 52,500

98 per cent of the days the Mean Density was within the range 11,000 to 70,000

These ranges in Mean Density are a measure of the variation in real changes in level of quality, free of the influence associated purely with test procedure employed. It follows also that comparisons should be made in terms of Mean Density, not between individual MPN values.

Evaluation of Sewage Treatment Data

Fig. 21 illustrates an application of log-probability paper to the evaluation of coliform density of influent and effluent of Buffalo, N.Y.* sewage treatment works based upon 117 routine samples of 3 portions in each of 3 decimal dilutions taken 3 to 6 times daily except Sundays during the month of May 1949.

Line "A" is the distribution of the 117 MPN's of influent, indicating a reasonably straight line. The Mean Density is located at (a), 67,000 coliform per ml. (read on Y scale); and $\sigma_{(Log)}$ is 0.37.

The slope of line "A" is only slightly steeper than that expected for a 3 portion test procedure and hence Mean Density remained reasonably stable during the month, ranging from 56,000 to 80,000 for 90 per cent confidence.

Line "B" represents the distribution of 117 MPNs of effluent. Again a straight line is indicated with a Mean Density located at (b), 800 coliform per ml. (read on Y scale) and $\sigma_{(Log)}$ of 0.79. The slope of the effluent, line "B", is about twice as steep as that of the influent, line "A", and the standard slope expected for a 3 portion test procedure. This indicates at once that changes in level of Mean Density and therefore real changes in quality of effluent took place during the month. By projecting parallel to the standard slope for 3 portion test procedure from any desired probability intercept on line A to the 50 per cent probability gives the range in Mean Density for any desired confidence. If we assume that samples were taken at equal intervals (approximately true) it can be reasoned that

50 per cent of the time Mean Density was above or below 800 per ml.

50 per cent of the time Mean Density was within the range 400 to 1,600 per ml.

90 per cent of the time Mean Density was within the range 145 to 4,500 per ml.

The disinfection efficiency of the treatment system is determined by comparison of the Mean Densities of the influent and effluent, 68,000 per ml. and 800 per ml. respectively, indicating an average reduction in bacterial density of 98.8 per cent.

V—Tests for Statistical Significance

Comparison is a common method of appraisal. Observed differences or similarities may not be significant, as they may arise solely by chance. The purpose of this article is to present graphical methods to test the statistical significance of such apparent differences before drawing conclusions from comparisons.

Tests for statistical significance cannot *prove* a cause and effect relationship. The contribution of statistics is to define the expected variations due to chance. Actually, any difference in results, no matter how great, can always be ascribed to chance, but a point is reached where the probability that the difference is due to chance becomes so small that the investigator prefers to ascribe the difference to other causes. The decision that the difference is not due to chance and the subsequent search for the underlying *cause* of the difference is completely outside the realm of statistical technique and is entirely a matter of professional judgment of the specialist in the field. The statistical method is only a tool, not a substitute for reasoning.

*Data courtesy of George Fynn, Chief Chemist.

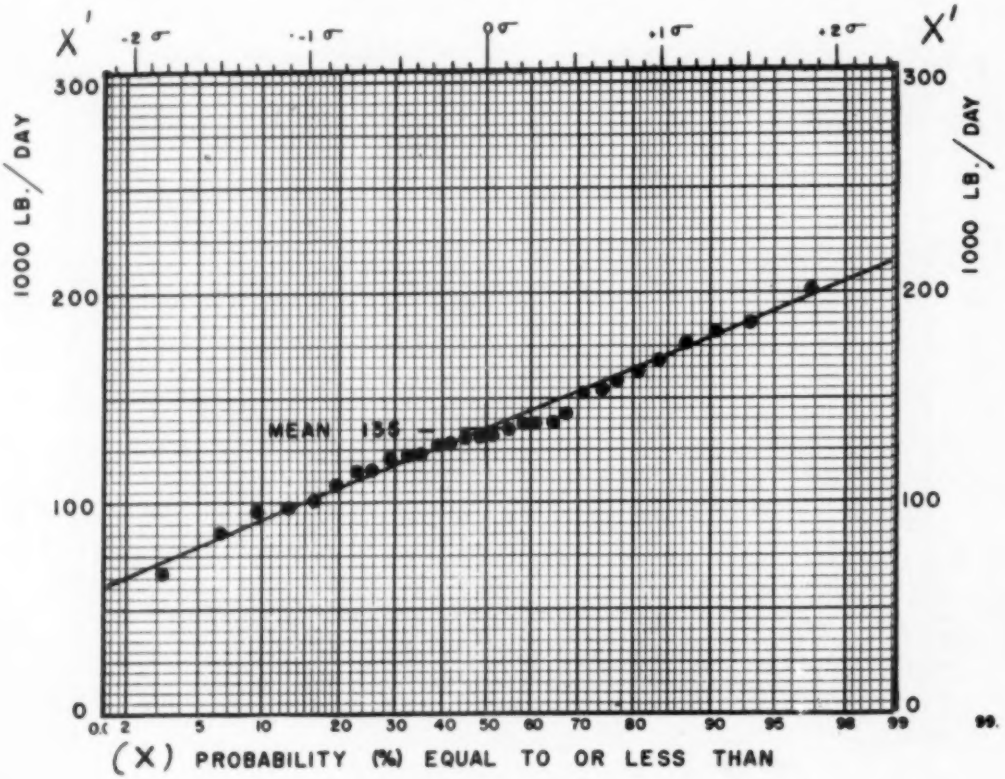


Fig. 22—Illustration of a Normal Distribution of Suspended Solids (Buffalo Sewage Works—Nov. 1939—Data Supplied by Geo. Fynn.)

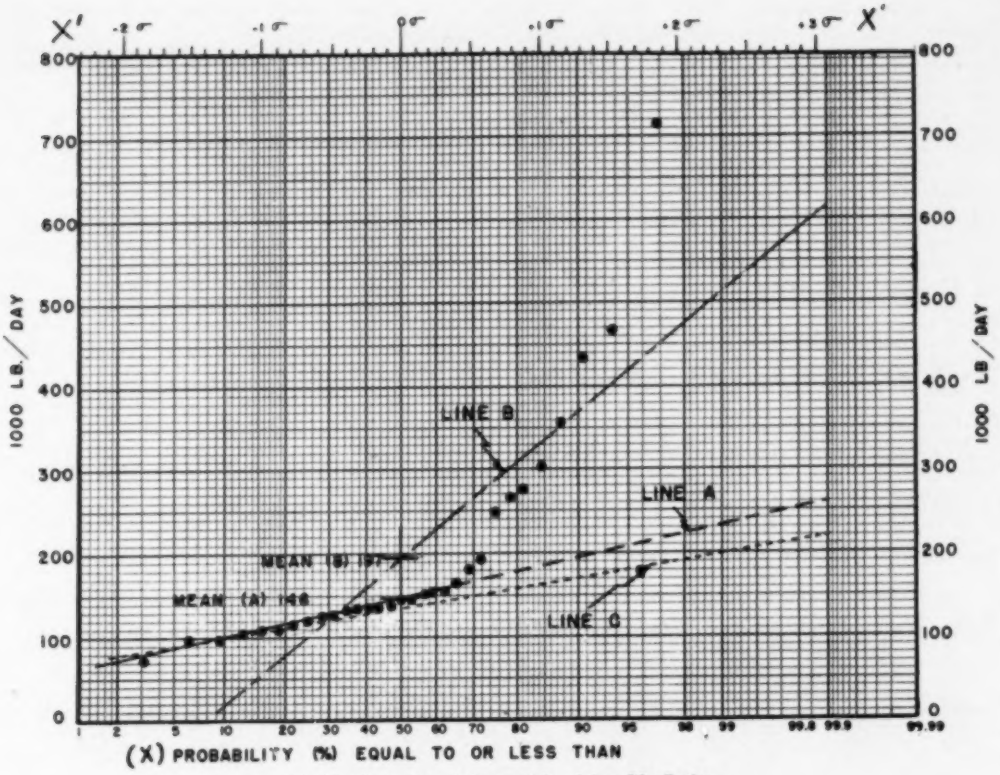


Fig. 23—Illustration of Abnormal Break in a Distribution
(Suspended Solids in Buffalo Sewage—Aug. 1939—Data Supplied by Geo. Fynn)

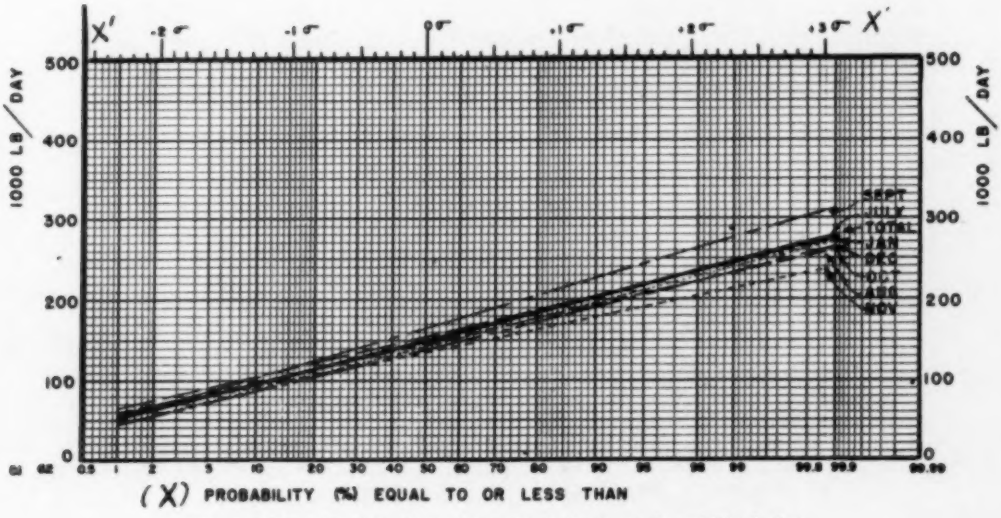


Fig. 24—Illustration of Graphical Test for Similarity Among Several Distributions

Testing a Single Series

Normality

The most important test applied to a single series is to determine if the distribution of individual measurements is *normal*. Graphically this is accomplished by plotting the data on probability paper described in the preceding articles. If a straight line is formed, the distribution is normal and symmetrical; if curved upward or downward, the distribution is skewed and asymmetrical. This is at once visually apparent. If a distribution plots as a straight line (is normal), then the raw data may be condensed, without loss of significance, to three summary figures:

(1) The Mean (Arithmetic Average)
(2) The Standard Deviation (σ)
(3) The Number of Observations (n)

Such a normal distribution is illustrated in Fig. 22, Suspended Solids for Buffalo Sewage for the Month of November 1939. Suspended solids are expressed on a quantitative basis computed from the concentration in parts per million and the daily volume of sewage in million gallons. Since a straight line is formed, the distribution is normal and may be summarized by the three statistics:

Mean ($\bar{Y}$ graphical)	= 135.
Standard Deviation (σ graphical)	= 34.
Number of Observations (n)	= 30.

However, if a distribution does not form a straight line (is not normal), such summary statistics can be very misleading. The superiority of the graphical approach over the usual analytical methods is illustrated in the following examples.

Abnormal Breaks in Data

Routine water and sewage treatment works operating data are at times subject to abnormal breaks in otherwise normal variations. This is usually associated with sudden hydrologic changes which radically alter conditions. Figure 23, Line A, shows a distribution of daily suspended solids determinations for influent of Buffalo Sewage Treatment Works for the Month of August 1939. A sharp break from an otherwise normal distribution (Line A) is noted at the right upper end. Precipitation records for August show that the values which break away from the distribution were associated with the first day of rainfall flushing the combined sewer system.

The question now arises, how shall such data be summarized? The best summary is the graphical plot itself, as this is the only method clearly to differentiate between the normal and abnormal segments without loss of significance. Neglecting the graphical approach and attempting condensation of data by analytical statistical methods alone leads to two common misrepresentations:

1. Neglecting to test for normality and computing an arithmetic average and a standard deviation gives

Mean ($\bar{Y}$ computed)	= 197.6 Thd. lb. per day
Standard Deviation (σ computed)	= 137.3 Thd. lb. per day
Number of Observations (n)	= 31

Such an analytical summary would lead one to believe that the distribution was normal and, if this mean and standard deviation are reconstructed on Fig. 23, it would produce a distribution represented by Line B. Visually, it is apparent that Line B is too high and too steep and is obviously inconsistent with the bulk of the actual data. In attempting to define both the normal and the abnormal segments, it defines neither and, in fact, gives a false summary which is "nonsensical" in relation to the actual observed facts. Such a summary is dangerous.

2. Excluding the abnormal values and then computing an arithmetic average and a standard deviation gives

Mean ($\bar{Y}$ computed)	= 132.6 Thd. lb. per day
Standard Deviation (σ computed)	= 27.5 Thd. lb. per day

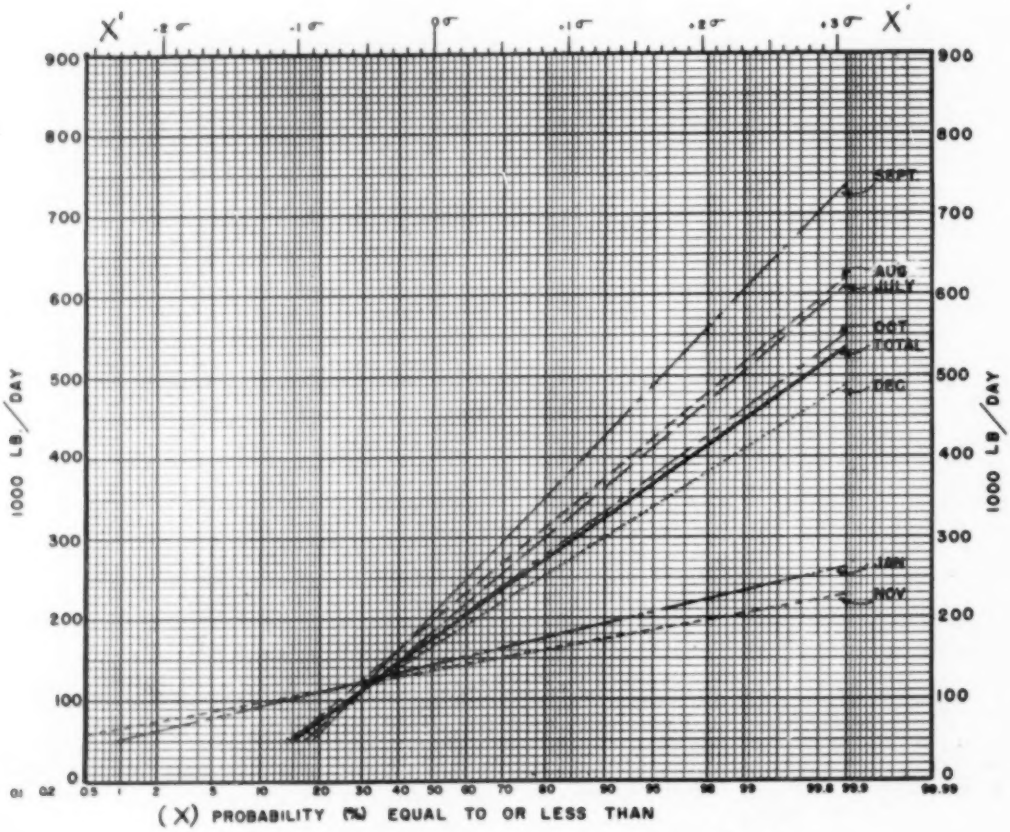


Fig. 25—Illustration of Graphical Test for Difference Among Several Distributions

Table 8

COMPARISON OF ANALYTICAL AND GRAPHICAL STATISTICAL SUMMARIES OF SUSPENDED SOLIDS

Buffalo Sewage Treatment Works Influent

July 1939-January 1940

Month 1939 (1)	Analytical Summaries: Computed mean 1000 lb./day (2)	Analytical Summaries: Computed σ 1000 lb./day (3)	n (4)	Graphical Summaries: Graphical mean (Normal segment) 1000 lb./day (5)	Graphical Summaries: Graphical σ (Normal segment) 1000 lb./day (6)	n (7)	Remarks (8)
July	182.9	139.3	31	153	39.0	31	85% normal followed by sharp break with 15% distinctly abnormal
August	197.6	137.3	31	146	37.3	31	65% normal followed by sharp break with 35% abnormal
September	206.1	173.5	30	166	48.0	30	75% normal followed by sharp break with 25% abnormal
October	174.0	123.1	31	139	40.0	31	80% normal followed by sharp break with 20% abnormal
November	134.9	30.8	30	135	34.	30	complete distribution normal
December	167.2	104.6	31	140	42.7	31	80% normal followed by sharp break with 20% abnormal
January, 1940	141.4	39.4	31	142	41.8	31	complete distribution normal
July, 1939-January, 1940	172.0	118.1	215	147	42.7	215	85% normal followed by sharp break with 15% abnormal

Number of observations (n) = 23. (8 largest values excluded)

This mean and standard deviation would reconstruct a distribution represented by Line C. Visually, Line C is too low and too flat. Excluding the 8 largest values completely ignores the abnormal segment and does not adequately represent the normal segment. Obviously, the deletion of the 8 largest values of a series of 31 values, even if they were in line with a normal distribution, would unduly reduce the mean and the standard deviation. "Throwing out" data is a dangerous procedure.

If a non-graphical condensation of data is insisted upon, it is best obtained through a graphical approach. Referring to Line A, Fig. 23, such a condensation of the raw data might be suggested as follows:

1. Approximately 65 per cent of the distribution is normal followed by a sharp break with the upper 35 per cent distinctly abnormal. (8 values distinctly out of line ranging from 248 to 717 Thd. lbs. per day)

2. The *normal* segment of the distribution is defined by

Mean ($\bar{Y}$ graphical)	= 146	Thd. lb. per day
Standard Deviation (σ graphical)	= 37.3	Thd. lb. per day
Total number of observations, normal and abnormal (n)	= 31.	

Such a summary, while no substitute for the actual published plot on probability paper, is at least consistent with the facts as observed and is not misleading.

As further emphasis of the value of the graphical approach, Table 8 contrasts the graphical summary statistics with the analytical summary statistics of the operating data for the Buffalo Sewage Treatment Plant for 7 months, July 1939-January 1940.

It will be noted from Table 8 that the normal suspended solids load to the treatment works from month to month, uninfluenced by rainfall flushes, is reasonably constant as reflected by the graphical means shown in Column (5). This is to be expected from a given population and normal industrial activity not subject to seasonal patterns. The day to day variability as reflected by the graphical standard deviation, Column (6), is also reasonably constant.

In contrast to this, there is a wide variation reflected in the analytical summary of computed monthly averages and standard deviations as shown in Column (2) and (3). November and January are of special significance because the complete distributions were normal without any breaks. Rainfall during these months was light and probably occurred as snow and hence flushing of the combined sewers did not take place. For the graphical summaries, it is noteworthy that the means and standard deviations of the other months tie in closely with these two months.

In contrast, however, the results of the analytical summaries show wide variations

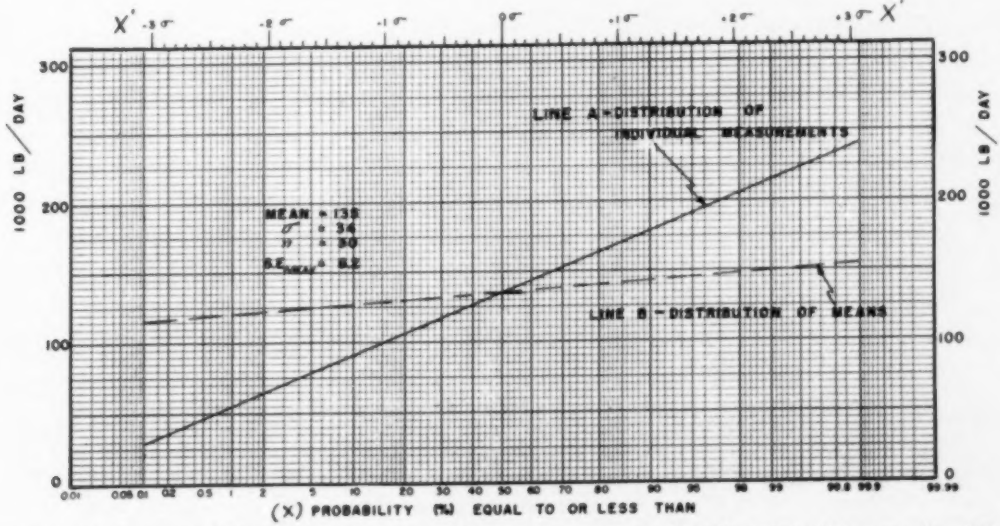

X' -3σ -2σ -1σ 0σ +1σ +2σ +3σ X'
300
200
100
0
1000 LB/DAY
LINE A - DISTRIBUTION OF INDIVIDUAL MEASUREMENTS
MEAN = 135
σ = 34
" = 30
S.E. MEAN = 8.2
LINE B - DISTRIBUTION OF MEANS
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
(X) PROBABILITY (%) EQUAL TO OR LESS THAN

Fig. 26—Distribution of individual measurements and the distribution of means—suspended solids, Buffalo, N.Y. sewage, Nov. 1939.

in means and standard deviations for the other months when compared with November and January. Note, also, that only when the complete monthly distribution is normal (November and January) do the analytical results approach the graphical.

In appraising treatment works loading and performance, it is obvious that the all too frequently employed "Monthly Average" may be a very misleading figure. It is essential to differentiate between the normal and the abnormal before drawing conclusions or making comparisons.

Testing Two or More Series

Differentiating Among Series

Plotting two or more series of data on the same sheet of probability paper affords a quick visual appraisal of similarities or differences. For example, assume that the distributions summarized on Table 8 are all normal distributions as represented by the means and the standard deviations. Figure 24 represents the reconstruction of the normal distributions of the graphical summaries, Columns (5) and (6) in Table 8. The eight distributions cluster about the common mean and disclose similar slopes. The visual pattern strongly suggests similarity among the distributions.

In contrast, reconstructing distributions from the analytical means and standard deviations of Columns (2) and (3) in Table 8 (Fig. 25) indicates marked differences among the distributions, not only as to position of the mean but also as to slope. Such graphical differentiation affords a quick appraisal and points out areas where further testing between two distributions may be warranted.

Overlapping Test

Statistical significance of the difference between two series of data can readily be evaluated by the overlapping test. In comparing two series, the first operation is to differentiate them by plotting both on the same probability paper. However, it is not sufficient to demonstrate two distinct distribution lines to be confident that there is a statistically significant difference between the two series. We expect, by chance alone, that there will be shifts in the distribution lines upward and downward in plotting similar repeated sample series. Hence, to demonstrate a statistically significant difference, two distributions must remain beyond such shifts in position which chance alone can reasonably be expected to produce.

The Standard Error (S.E.) of the Mean is one measure of such shifts in a distribution line.

$$\underset{(\text{Mean})}{\text{S E}} = \frac{\sigma}{\sqrt{n}} \qquad (1)$$

The stability or reliability of the mean, as defined by its standard error, varies directly as the standard deviation (σ) of the individual measurements and inversely as the square root of the number of measurements in the series. The variability of the individual measurements is inherent in the phenomenon being observed and not much can be done about this. However, it is possible to control the reliability of a mean simply by increasing the number of individual measurements. Increasing the number of measurements four fold reduces the S E of the mean by ½; 16 fold by ¼; etc.; or more generally from the transformation of equation (1), the number of individual measurements required for a specified standard error of the mean is given by

$$n = \frac{\sigma^2}{(\text{S E})^2} \qquad (2)$$

For example (Referring to Fig. 26), the mean ($\bar{Y}$) and standard deviation (σ) as determined graphically are 135 and 34 Thd. lb. per day respectively for the series involving 30 individual measurements. From this single series it is then possible to evaluate the reliability of the mean

$$\underset{(\text{Mean})}{\text{S E}} = \frac{\sigma}{\sqrt{n}} = \frac{34}{\sqrt{30}} = 6.2$$

Variation of the mean, like variation of the individual measurements, follows the normal probability distribution and from this it can be expected that for repeated series of 30 measurements

68% of the means would fall within the range of
135 ± 1 S E or 135 ± 6.2;
95% of the means would fall within the range of
135 ± 2 S E or 135 ± 12.4;
99.73% of the means would fall within the range of
135 ± 3 S E or 135 ± 18.6

This defines the range in shift upward or downward that can be expected by chance alone from plotting repeated series of only 30 individual measurements made under the same conditions.

The distribution of *means* can be represented graphically on probability paper sim-

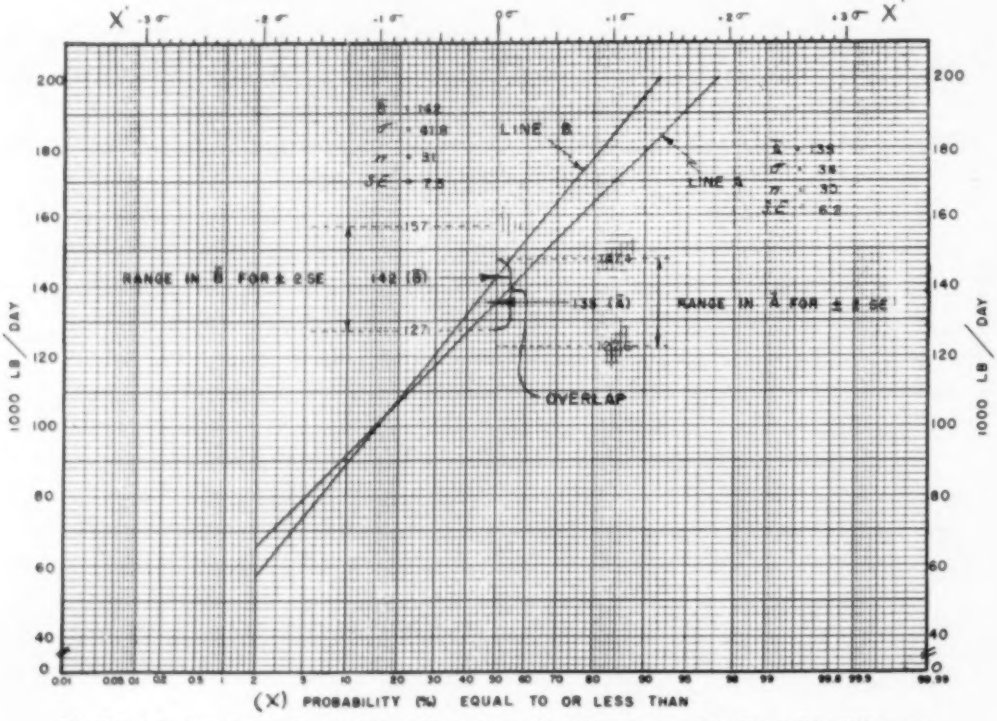

X' -3σ -2σ -1σ 0σ +1σ +2σ X'
LINE B
LINE A
RANGE IN B FOR ± 2 SE (42) (B)
135 (A)
RANGE IN A FOR ± 2 SE
OVERLAP
1000 LB / DAY
(X) PROBABILITY (%) EQUAL TO OR LESS THAN

Fig. 27—Illustration of overlapping test between Nov. and Jan. distributions of suspended solids, Buffalo, N.Y. sewage.

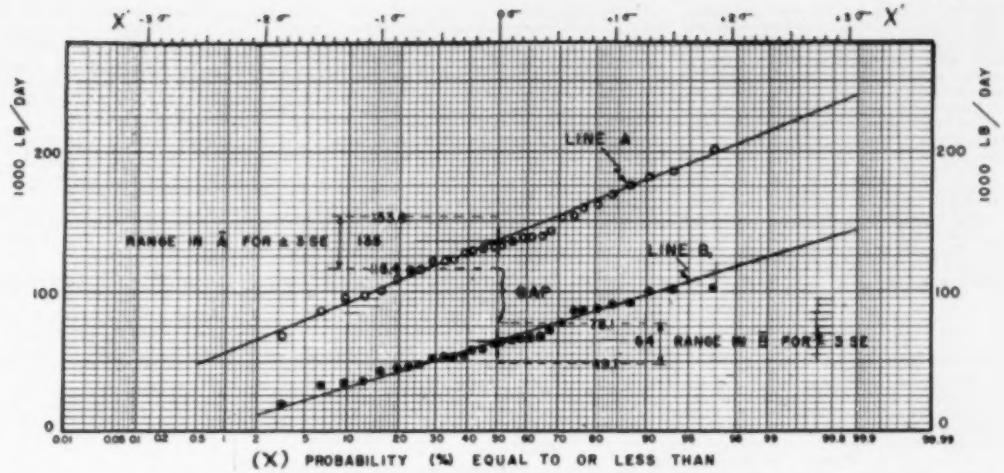

X' -3σ -2σ -1σ 0σ +1σ +2σ +3σ X'
1000 LB/DAY
200
100
0
LINE A
LINE B
RANGE IN Ā FOR ± 3 SE
135
GAP
RANGE IN B̄ FOR ± 3 SE
64
0.01 0.05 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
(X) PROBABILITY (%) EQUAL TO OR LESS THAN

Fig. 28—Illustration of overlapping test between influent and effluent suspended solids, Buffalo, N. Y. sewage, Nov. 1939.

ply by laying off a line through the mean of a single series at a slope equivalent to the S E where X' scale is in terms of S E in place of σ. The expected distribution of means from repeated series of 30 measurements is thus represented by Line B on Fig. 26. From this line, it is possible to read the range in means for any desired probability in the same manner that ranges in individual measurements can be read from Line A.

With the range in shifts of the distribution thus defined by the standard error of the mean, it is now possible to apply the overlapping test for the statistical significance of the difference between two distributions. Marking off these ranges about the mean of each series graphically discloses the variation expected by chance alone at any confidence level.

If no overlap develops between the ranges, then chance may be ruled out and the difference between the two series being compared is accepted as statistically significant.

If an overlap develops between the two ranges, or if one range encloses the other, chance cannot be ruled out, and the difference between the two series is not accepted as statistically significant.

It will be noted that the range of the mean is dependent upon a choice of a confidence level. The acceptance of a 95 per cent confidence range within which the mean is expected to vary by chance defines a specific range ± 2 S E. But ruling out chance at this range implies a risk of being wrong about 5 times in 100, as chance alone can be expected to show a mean outside the range of ± 2 S E about five times in 100. Setting a range of ± 3 S E is generally interpreted as "practically certain" to account for variation associated with chance, but even here, there is a risk of being wrong 27 times in 10,000, as chance can be expected to show a mean outside the range of ± 3 S E about three times in a thousand. The decision as to a confidence level always rests with the investigator and will vary depending upon the nature of the problem and the consequences of being wrong.

Another factor to be considered is that the reliability of a mean can be changed by the number of individual measurements. Hence, comparison between two means, each based upon a small number of observations, may develop an overlap and for these sized series, the difference would be considered not statistically significant. Increasing the number of measurements would reduce the range and may conceivably not develop an overlap and for the larger series, the difference then would be considered statistically significant.

Figure 27 illustrates an application of the overlapping test in comparing the suspended solids of the influent for the month of November with that of the month of January. Line A represents the distribution of the 30 individual measurements for November giving a mean of 135 and a standard deviation of 34 Thd. lb. per day. Line B represents the distribution of the 31 individual measurements for January giving a mean of 142 and a standard deviation of 41.8 Thd. lb. per day. Two distributions are formed with an apparent difference between the means of 142 — 135 or 7 Thd. lb. per day. The standard error of the means are $\frac{34}{\sqrt{30}}$ or 6.2 for November; and $\frac{41.8}{\sqrt{31}}$ or 7.5 for January. The question now is, is this difference statistically significant or can it reasonably be ascribed to chance variations associated with such small number of observations? In making a decision in this instance about chance variation in the means, we do not wish to be wrong more often than 5 times in 100. This requires defining the range in means by ± 2 S E; 135 ± (2 x 6.2) or 122.6 to 147.4 for $\bar{A}$; and 142 ± (2 x 7.5) or 127 to 157 for $\bar{B}$. Laying off ± 2 S E about each mean produces a large overlapping and therefore there is *no* statistically significant difference between the two distributions. Chance alone can easily account for the apparent difference, in fact the positions of the two lines could reverse themselves; November could be above January.

Figure 28 is a second illustration of the application of the overlapping test. Line A represents again the distribution of the influent suspended solids for November, while Line B represents the suspended solids of the effluent for November. The mean of the influent is 135 with a S E of 6.2 Thd. lb. per day, while the effluent mean is 64 with an S E of 4.7 Thd. lb. per day. As is to be expected, there is a substantial difference between the influent and the effluent distribution lines (135 — 64) or 71 Thd. lb. per day. In this instance, we wish to be "practically certain" (99.73%) that the difference is beyond what can be ascribed to chance. This defines a range about the means of ± 3 S E. Laying off ± 3 S E about each of the means does *not* produce an overlapping, in fact a considerable gap still separates the two distributions and hence, we conclude that there *is* a statistically significant difference.

Since in this illustration we are comparing influent and effluent, an opportunity is afforded to appraise the monthly efficiency of the treatment works. The most probable efficiency would be that reflected by the difference between the two means, a removal of (135 — 64) or 71 Thd. lb. per day or an efficiency of 71/135 or 52.5%. A very severe criterion by which monthly efficiency could be judged would be to compare the lowest range of the influent with the highest range of the effluent. This would give a removal of (116.4 — 78.1) or 38.3, an efficiency of 38.3 ÷ 116.4 or 33%.

Another approach to efficiency would be to compare each daily influent and effluent and then plot the daily efficiencies on probability paper to define the nature of the daily variation, as shown in Fig. 29. Here the graphical mean daily efficiency for the month is 53%, which is in close agreement with the 52.5% previously determined from monthly mean results. It will be observed from Fig. 29 that there is considerable variation in day to day efficiency with a standard deviation of 12.7%.

Number of Measurements Controlling Reliability of Mean

Frequently one is asked the question, how many measurements are necessary? The answer to this depends upon what reliability will be accepted and also foreknowledge of the nature of the inherent variability of the individual measurements. The first is a matter of decision, the second may be estimated from previous experience or from a trial run. Take, for example, the monthly mean influent suspended solids for Novem-

ber, 135 Thd. lb. per day with a standard deviation of 34. If it is decided to control the variation of the mean to a standard error of 2, how many individual measurements will be required? Accepting the trial σ of 34 and the specified S E of 2, the required number of individual measurements is then readily determined from equation (2)

$$n = \frac{\sigma^2}{(S\,E)^2} \text{ or } \frac{34^2}{2^2} \text{ or } 289.$$

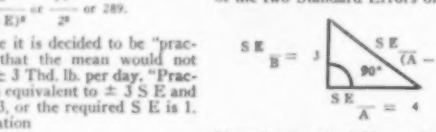
Or let us suppose it is decided to be "practically certain" that the mean would not vary more than ± 3 Thd. lb. per day. "Practically certain" is equivalent to ± 3 S E and hence 3 S E = 3, or the required S E is 1. For this specification

$$n = \frac{34^2}{1^2} = 1156$$

Difference Between Two Means

The simple overlapping test is a severe criterion for determining the statistical significance of a difference between two distributions. The assumption is made that the distributions approach each other; that is, as the smaller increases, the larger decreases. This requires a relative shift of 180° and hence the distance required to keep the distributions from overlapping is some increment of the sum of the Standard Errors of the two distributions. For example, if the Standard Error of the mean of Series A is 4 units and that of Series B is 3 units, 68 per cent certainty of a statistically significant difference would require the two distributions to be at least 3 + 4 units apart; 95 per cent certainty, 2 (3 + 4) apart; and "Practically Certainty" (99.73 per cent), 3 (3 + 4) apart. The overlapping test, therefore, defines the Standard Error of a *difference* between two means as the sum of Standard Errors of the two means.

If two series are free to shift independently of each other, they need not necessarily always vary by 180°. Actually the independent shifting of two distributions may conceivably have an average variation in relation to each other at 90°. The relative difference between two means then would be equivalent to the hypotenuse of the right triangle with the legs comprised of the two Standard Errors of the means.



Now the Standard Error of the difference between the two means is the square root of the sum of the squares of the two Standard Errors of the means, which is the hypotenuse distance.

$$S\,E_{\bar{A}-\bar{B}} = \sqrt{(S\,E_{\bar{A}})^2 + (S\,E_{\bar{B}})^2}$$

or in the example:

$$\sqrt{4^2 + 3^2} = \sqrt{25} = 5$$

It will be noted that while the Standard Error of the difference between the two means by the overlapping test is 3 + 4 or 7, by assuming complete independence the Standard Error of the difference is

$$\sqrt{3^2 + 4^2} \text{ or } 5.$$

Thus the overlapping test is unduly severe.

Assuming the independence between two means, employing the hypotenuse as the unit of Standard Error of the difference, the test for statistical significance between two means would proceed as follows:

1. Plot the two distributions to test for normality.
2. If normal, obtain the mean and standard deviation (σ) of each series.
3. Compute the Standard Error of each mean.

$$S\,E_{Mean} = \frac{\sigma}{\sqrt{n}}$$

4. Compute the Standard Error of the difference between the two means.

$$S\,E_{Diff.} = \sqrt{(S\,E_{Mean_1})^2 + (S\,E_{Mean_2})^2}$$

5. Obtain the difference between the two means.
6. Decide upon a confidence level for test criteria, 95 per cent certainty, or 99.73 per cent or any other level desired.
7. Apply the test for statistical significance of the difference.

For example, 95 per cent certainty:

Subtract from the difference, 2 times the Standard Error of the difference and, if a positive difference remains, it can be concluded that the difference is statistically significant at this level of confidence. If, after subtracting, no positive difference remains or if a negative value occurs, then the difference was completely washed out by chance alone and it can be concluded that the apparent difference between the two means is *not* statistically significant.

Applying this criterion to the two illustrations employed in the overlapping test: From Fig. 27

Series A (November)	Series B (January)
Mean = 135	Mean = 142
$S\,E_{\bar{A}}$ = 6.2	$S\,E_{\bar{B}}$ = 7.5

Difference = 142 − 135 = 7

$$S\,E_{(Difference)} = \sqrt{6.2^2 + 7.5^2} = 9.7$$

Test at 95% certainty:

$$7 - (2 \times 9.7) = -12.4$$

The difference is completely washed out by

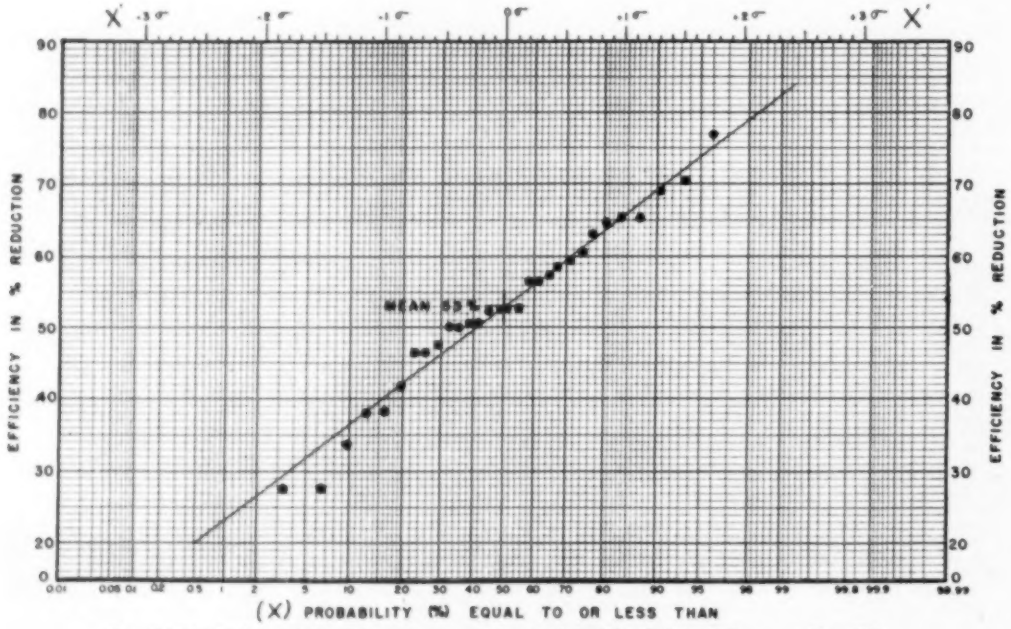


Fig. 29—Distribution of daily efficiency in removal of suspended solids—Buffalo, N.Y. sewage, Nov. 1939.

chance alone; therefore the apparent difference is *not* statistically significant.
From Figure 28.

Series A Influent: Mean = 135; S E (A) = 6.2
Series B Effluent: Mean = 64; S E (B) = 4.7

Difference = 135 − 64 = 71

$$S\,E_{(Difference)} = \sqrt{6.2^2 + 4.7^2} = 7.8$$

Test at (99.73%) "Practical Certainty":
71 − (3 × 7.8) = +47.6

A substantial positive difference remains after deducting practically all that can be accounted for by chance; therefore there *is* a statistically significant difference.

Historical

In concluding this series, reference to a few pioneering applications of statistics to sanitary engineering is appropriate. The profession is indebted to the early pioneering work of Professor Earle B. Phelps who made wide use of statistical tools; to the late Allen Hazen for his development of probability paper and its application to storage requirements and to flood probability; to Professor Gordon M. Fair for his early use of statistics as a research tool; to C. E. Keefer for his early application of probability paper to evaluation of sewage treatment operating data; and more recently to Professor E. J. Gumbel for his development of standard distribution of extreme values.

In preparation of this series, the writer wishes gratefully to acknowledge the assistance rendered by three Georges: i.e., Symons, (Man. Ed., *Water & Sewage Works*), Fynn (Ch. Chem., Buffalo Sewer Authority) and Hazey (Ch. Oper. Filter Plant, Wyandotte, Mich.) for supplying a considerable volume of data for analysis. The writer wishes also, gratefully to acknowledge the extensive and painstaking computations of Mrs. Mildred Harter.

Fire Flows Required for Towns of Various Sizes, by National Board of Underwriters

Population	Required Fire Flow, Gallons per Minute for Average City
1,000	1,000
2,000	1,500
4,000	2,000
6,000	2,500
10,000	3,000
12,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000
125,000	10,000
150,000	11,000
200,000	12,000

Over 200,000 population, 12,000 gallons a minute, with 2,000 to 8,000 gallons additional for a second fire.

In residential districts the required fire flow depends upon the character and congestion of the buildings. Sections where buildings are small and of low height and with about one-third the lots in a block built upon, require not less than 500 gallons a minute; with larger or higher buildings up to 1,000 gallons is required, and where the district is closely built, or buildings approach the dimension of hotels or high value residences, 1,500 to 3,000 gallons is required, with up to 6,000 gallons in densely built sections of 3-story buildings.

Commercial Pipe Sizes for Fire Streams*

Number of 1 1/4-Inch Hose Nozzles	Ordinary Fire Streams											
	40 Pounds Pressure		50 Pounds Pressure		60 Pounds Pressure		70 Pounds Pressure		80 Pounds Pressure		90 Pounds Pressure	
	Required Size Pipe In.	Flow Cu. Ft. per Min.	Required Size Pipe In.	Flow Cu. Ft. per Min.	Required Size Pipe In.	Flow Cu. Ft. per Min.	Required Size Pipe In.	Flow Cu. Ft. per Min.	Required Size Pipe In.	Flow Cu. Ft. per Min.	Required Size Pipe In.	Flow Cu. Ft. per Min.
1	4	20	6	23	6	25	6	27	6	29	6	30
2	6	40	8	45	8	50	8	53	8	57	8	61
3	8	61	8	68	10	74	10	80	10	86	10	91
4	10	81	10	90	10	99	10	107	12	114	12	121
5	10	101	12	113	12	124	12	134	12	143	12	152
6	12	121	12	135	12	149	14	160	14	172	14	182
7	12	141	14	158	14	174	14	187	14	200	16	212
8	12	162	14	181	14	199	16	214	16	229	16	242
9	14	182	14	203	16	223	16	241	16	257	18	273
10	14	202	16	226	16	248	16	267	18	286	18	303
11	16	222	16	248	18	273	18	294	18	314	18	333
12	16	243	18	271	18	298	18	321	20	343	20	364
13	16	263	18	293	18	323	20	348	20	372	20	394
14	18	283	18	316	20	348	20	374	20	400	20	424
15	18	303	20	339	20	372	20	401	20	429	24	455

	High-Pressure Fire Streams											
	100 Pounds Pressure		110 Pounds Pressure		120 Pounds Pressure		130 Pounds Pressure		140 Pounds Pressure		150 Pounds Pressure	
1	6	32	6	33	6	35	6	36	6	38	6	39
2	8	64	8	67	10	70	10	73	10	75	10	78
3	10	96	10	100	10	105	10	109	12	113	12	117
4	12	128	12	136	12	140	12	145	12	151	14	156
5	14	160	14	167	14	174	14	181	14	188	14	195
6	14	191	14	200	14	209	16	218	16	226	16	234
7	16	223	16	234	16	244	16	254	16	264	18	273
8	16	255	16	267	16	279	18	290	18	301	18	313
9	18	287	18	301	18	314	18	326	18	339	20	352
10	18	319	18	334	20	349	20	363	20	377	20	391
11	20	351	20	367	20	384	20	399	20	414	20	430
12	20	383	20	401	20	419	20	435	24	452	24	469
13	20	415	20	434	24	454	24	472	24	490	24	508
14	24	447	24	467	24	488	24	508	24	528	24	547
15	24	479	24	501	24	523	24	544	24	565	24	586

To convert cubic feet to gallons, multiply by 7.4805.
In calculating above table, the following assumptions were made: Nozzles, 1 1/4-inch smooth bore, playing simultaneously, and attached to 300 feet of best quality rubber-lined hose; pressures measured at hose connections; velocity of water in pipe approximately 3 feet per second.

TABLE OF EFFECTIVE FIRE STREAMS

Using 100 feet of 2½-in. ordinary best quality rubber-lined hose between nozzle and hydrant or pump.

Smooth Nozzle, Size	¾ Inch						7/8 inch				
Pressure at Hydrants, lbs.	32	43	54	65	75	86	34	46	57	69	80
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100' 2½" hose	2	3	4	5	5	6	4	6	7	9	10
Vertical Height, feet	48	60	67	72	76	79	49	62	71	77	81
Horizontal Distance, feet	37	44	50	54	58	62	42	49	55	61	66
Gallons Discharged per min.	90	100	116	127	137	147	123	142	159	174	188

Smooth Nozzle, Size	1 Inch						1⅛ Inch				
Pressure at Hydrant, lbs.	37	50	62	73	85	97	41	54	67	80	93
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100' 2½" hose	7	10	12	13	15	17	11	14	17	20	23
Vertical Height, feet	51	64	73	79	85	89	52	65	75	83	88
Horizontal Distance, feet	47	55	61	67	72	76	50	59	66	72	77
Gallons Discharged per min.	161	186	208	228	246	263	206	238	266	291	314

Smooth Nozzle, Size	1¼ Inch						1⅜ Inch				
Pressure at Hydrant, lbs.	46	60	75	90	104	119	52	69	86	102	119
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost per 100' 2½" hose	16	20	25	30	34	39	22	29	36	42	49
Vertical Height, feet	53	67	77	85	91	95	55	69	79	87	92
Horizontal Distance, feet	54	63	70	76	81	85	56	66	73	79	84
Gallons Discharged per min.	253	292	326	357	386	413	307	354	396	434	469

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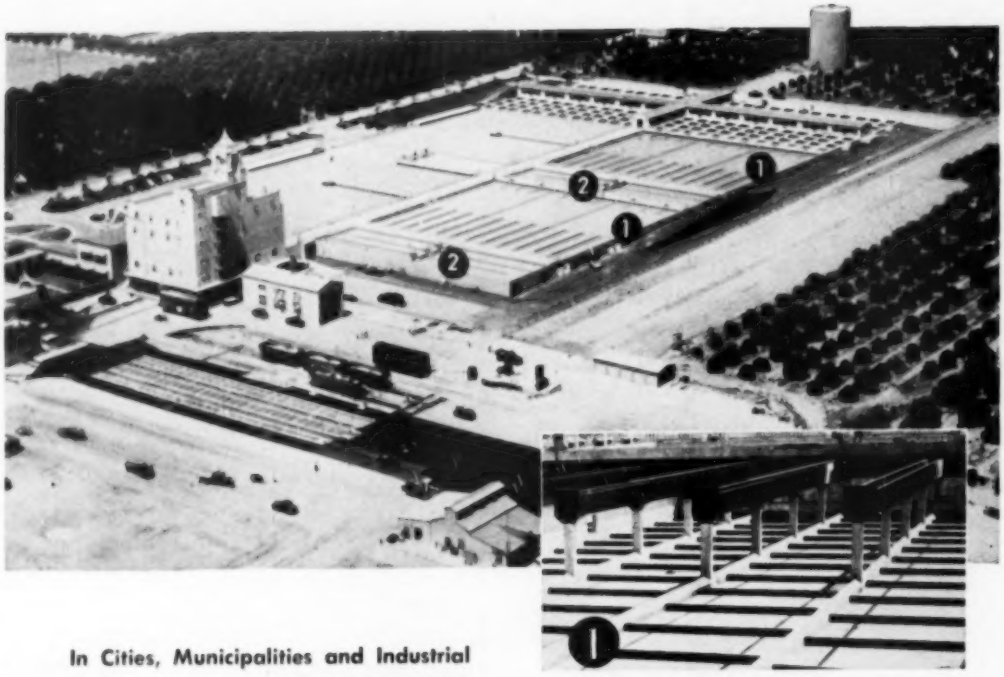
Plus LINK-BELT quality components . . . Combine to solve your Water, Sewage, and Industrial Waste Treatment problems



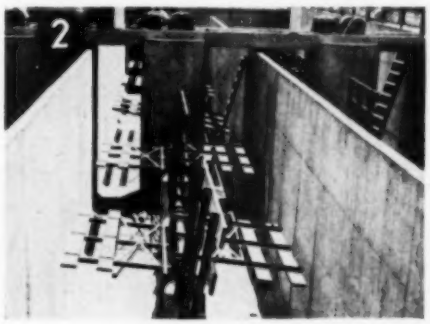
Straightline Collectors

Two 200 x 200 ft. settling tanks at La Verne, California, have Straightline Collectors indicated by No. 1. Peak-cap bearings, pivoted flights, and "Straightline Action" mean top efficiency.

In Cities, Municipalities and Industrial Plants everywhere, Link-Belt equipment provides reliable, efficient service.

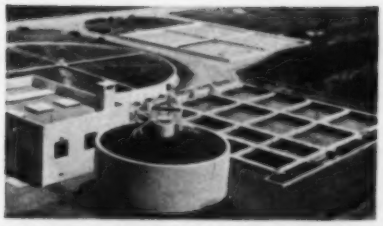
Get the finest in modern Water, Sewage, and Industrial Liquid Waste Treatment Equipment. It can be as simple as calling in a Link-Belt Sanitary Engineer while you are still in the planning stage. For the Link-Belt line is designed and built to the highest standards and backed by more than 30 years' experience in this field.

Link-Belt Sanitary Engineers will be glad to work with your engineers, chemists and consultants to get the best in modern treatment equipment.



Straightline Mixers

Straightline Paddle Mixers (No. 2 above) provide gentle rolling action in two 48 x 200 ft. mixing tanks. Drive units for all tanks are Link-Belt Electro-Fluid Drives with "Cushion Action."

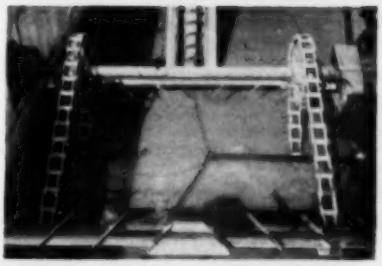


◀ Bio-Filtration Systems
This system consists of high rate shallow filters and recirculation of the effluent from the filter to the settling tanks, in single-stage or two-stage treatment, as required.

Scum Breakers ▶
Used in either round or rectangular digestion tanks to break up the floating scum, and to paddle down and submerge it.

◀ Circuline Collectors
"Straightline Action" assures quick and positive sludge removal from the entire tank floor in one revolution.

Grit Collectors and Washers ▶
Effectively collect, wash and remove settled grit and separates it from putrescible organic matter.



Thru-Clean Bar Screens

A coarse bar rack and chain operated rakes equipped with fingers that clean thru the rack from the back. The screen cannot be jammed by large objects since the rake will enter under and lift them.

Straightline Bar Screens

For removal of floating solids over ½" in size, from incoming sewage or industrial liquids, thus protecting the equipment in the following plant units.

Tritor Screens

For the removal of screenings and grit at small sewage treatment plants. With the Tritor Screen, one mechanism accomplishes removal of both grit and screenings.

Flash Mixers

For rapid and thorough mixing of chemicals with water, sewage or industrial liquids. A large four-blade propeller operates without under-water bearing.

Liquid Screens

An efficient and economical screen for the removal of solids from industrial liquids. Units are available in several sizes with coarse or fine screen medium.

Other Products Include

Air Diffuser Units; Non-Clogging Spray Nozzles; Traveling Water Intake Screens; Rotary Screens; Roto-Louvre Sludge Dryers; Chemical Handling Machinery; Car Spotters and Haulage Systems; and a complete line of Elevating, Conveying, and Power Transmission Machinery. Catalogs sent on request.

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"Modern Processes and Equipment for Sewage and Industrial Waste Treatment"

PROCESS...AND EQUIPMENT...FOR SEWAGE AND INDUSTRIAL WASTE

ACTIVATED SLUDGE TREATMENT

BIO-ACTIVATION PROCESS—a patented system utilizing the best qualities of trickling filters and activated sludge. Pre-treatment (pre-aeration and grease flotation) is employed to increase the efficiency of primary settling so as to prevent overloading of secondary treatment. Primary treatment is followed by high capacity filters and short period intermediate sedimentation. Here, initial high removals of B.O.D. are obtained before sewage is passed to aeration tanks where activated sludge is developed. Because of the intermediate filter treatment which considerably reduces the strength of the primary effluent, the liquor can be readily handled by the activated sludge process without the usual upsets caused by exceptional conditions and shock loads.

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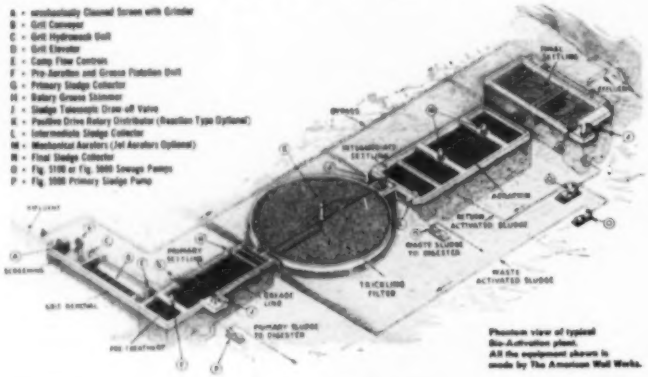
A - Simultaneously Cleaned Screen with Grinder
B - Grit Conveyor
C - Grit Hydrowash Unit
D - Grit Elevator
E - Camp Flow Control
F - Pre-Aeration and Grease Flotation Unit
G - Primary Sludge Collector
H - Rotary Grease Skimmer
I - Sludge Telescopic Draw-off Valve
K - Positive Drive Rotary Distributor (Reaction Type Optional)
L - Intermediate Sludge Collector
M - Mechanical Aerators (Jet Aerators Optional)
N - Final Sludge Collector
O - Fig. 5100 or Fig. 3600 Sewage Pumps
P - Fig. 5500 Primary Sludge Pump
INFLUENT
SCREENINGS
PRIMARY SETTLING
GREASE
INTERMEDIATE SETTLING
EFFLUENT
AERATION
RETURN ACTIVATED SLUDGE
WASTE SLUDGE TO DIGESTER
TRICKLING FILTER
WASTE ACTIVATED SLUDGE
DRAINAGE LINE
PRIMARY SLUDGE TO DIGESTER
FROM DIGESTER

Phantom view of typical Bio-Activation plant. All the equipment shown is made by The American Well Works.

MECHANICAL AERATION—Consists of a circulating pump with downdraft tube and hydraucone assembly. As liquor passes through the pump, fine bubbles of air are drawn in and intimately mixed with the sewage. This mixture is ejected at high velocity across the tank floor. Consequently, entrained air is distributed uniformly across the tank, and fine air bubbles, rising slowly to the surface, supply sufficient oxygen to maintain the activated sludge process. For large installations, "AMERICAN" Aerators are installed in single, large tanks without dividing walls because the pattern of recirculation sets up hydraulic baffles betwten the units, thereby eliminating any possibility of short circuits.

Send for Bulletin No. 265

JET AERATION—Injects an intimate mixture of liquor and finely divided air into the aeration tank. No other method of aeration produces the unusually high rate of oxygen absorption at remarkably low cost. Additional aeration economically provided for existing plants. Present diffuser plate or tube installations easily replaced.

Fully Described and Illustrated in Manual No. 149

ROTARY DISTRIBUTORS—Reaction and Positive Drive Types. The Reaction type is manufactured with 2, 3, 4, or 6 arms. In general, the 3 arm distributor has the advantage of minimum wind effect, low starting inertia, and perfect balance. The Positive Drive type is rotated continuously independent of the sewage flow, by a motorized gear reduction unit. It is used under conditions of low available head and wide variations in flow. "AMERICAN" Distributors are equipped with a patented dual oil seal which eliminates troublesome and costly mercury, protects bearing surfaces, and will withstand at least 10' of water pressure.

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Send for Technical Supplement TV on Telescoping Sludge Valve

GRIT REMOVAL

AMERICAN CAMP REGULATOR—an adjustable control to maintain velocity of sewage flow thru grit channels at optimum rate, regardless of rate of flow thru plant.

GRIT CONVEYOR—single strand, drag type. Carries grit to hopper for washing and removal.

GRIT HYDROWASH—grit washed free of organic matter by turbulent downflow recirculation of liquor in grit hopper.

GRIT ELEVATOR—tube type, totally enclosed for lifting well-drained grit to desired height. Manual or automatic operation.

Send for Bulletin 249A

American Camp Regulator for Grit Channels

Send for Technical Supplement "CR"

SCREENING

MECHANICALLY CLEANED BAR SCREEN AND GRINDER—designed for wide range of channel widths, settings, and arrangements. Grinder attached to sorting tray . . . shredded screenings returned to sewage flow.

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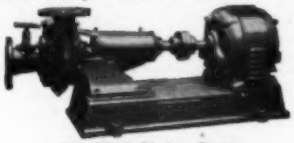
PRE-TREATMENT

GREASE FLOTATION UNIT—removes grease and oils, produces simultaneous aeration and agitation, and oxidizes objectionable odors. *Send for Bulletin No. 260A*



No. 5500 Sludge Pump

SLUDGE REMOVAL

POSITIVE FLIGHT CONVEYORS—for rectangular settling tanks.

CIRCULAR CLARIFIERS—for round settling tanks.

SLUDGE AND SEWAGE PUMPS—Fig. 5500 cutting type primary sludge pump. Fig. 5100 enclosed impeller type raw sewage pumps. Fig. 5600 single vane impeller type sewage pumps. Fig. 3400 recirculation pumps. This line of horizontal and vertical pumps ranges in size from 3" to 18" inclusive, in capacity from 40 to 10,000 GPM, and in head from 5' to 85'.

Send for Bulletins No. 237A, 250A, 253A, 261A

FINANCING SEWERAGE IMPROVEMENTS

By ROBIE L. MITCHELL
Attorney
Mitchell and Pershing, New York, N.Y.

The author of this article, with a background of experience in developing plans for financing sewerage improvements, drew up and later successfully defended the Sewer Revenue Ordinance of the City of Miami before the Florida Supreme Court.

In this important case the favorable decision won by Mr. Mitchell from Florida's Supreme Court not only established the constitutionality of the Sewer Service Charge method of financing sewerage improvements in the state of Florida, but also established a precedent of considerable importance in future cases of like nature in all parts of the country.

ONE of the most pressing problems in many urban communities is the disposal of sewage and industrial wastes. The pollution of our rivers, harbors and inland and coastal waters into which raw sewage and industrial wastes flow directly or are being pumped has not only impaired or destroyed their value for fishing and recreational purposes, but has already become a serious menace to the health of the people and this menace is increasing more and more with the rapid increase in our urban population. Some of our cities pump their water, including the water which is used in their homes, from rivers which are polluted upstream by the raw sewage of another city or by chemicals and wastes from some mill or factory. It would take a lot of persuasion to make me believe that any city or private corporation has the right so to pollute the rivers and harbors which God has given to all the people of this country.

What are we going to do about it?

For one thing, we can require private industry to clean up its own mess by treating it before dumping it into a river, or by running it through a city's sewage treatment plant and paying for the service.

Financing the Big Problem

Our big problem comes in financing the construction of the sewage treatment plant.

In the past the construction of sanitary sewers and sewage disposal systems has been financed for the most part by the issuance of general obligation bonds supported by taxes or by taxes and special assessments. In many cities special assessments for all or a portion of the cost of sanitary sewers have been levied upon the property abutting upon the improvement, whether such property is improved or unimproved. The balance of the cost and the cost of intercepting sewers, force mains, pumping stations and outlets and sewage treatment plants in the cases where they have them, have been borne by the taxpayers at large of the cities. As it is extremely difficult, if not impossible, to sell bonds payable solely from special assessments, the cities would issue their general obligation bonds payable from taxes, the amount of the taxes in each year being reduced by the amount of special assessment collections.

But constitutional limitations and restrictions on the issuance of bonds or the incurring of debt have caused us in recent years to consider the possibility and the feasibility of financing the construction of sewage disposal systems by the issuance of revenue bonds, the interest on which is payable solely from the proceeds of sewer service charges (sometimes referred to as sewer rental) to be imposed on those whose sewage is disposed of or treated by the system.

Legal Questions Involved

I was first called upon to draft legislation for this type of financing 17 years ago. We then had very few court decisions to help us as only a few cities had attempted to impose a charge for their sewers. We have been confronted with these legal questions:

1—What are sewer service charges? Are they related to the taxing power, or are they to be classified as special assessments based on benefits? If the former, must the proposed bonds be authorized at an election or must they be included in computing constitutional or statutory debt limits? If they are to be treated as special assessments, should not provision be made for a public hearing after proper notice? Or are they to be treated merely as charges for services rendered?

2—On what factors should the sewer charges be based?

3—How shall the collection of delinquent charges be enforced?

In 1945 I drafted legislative acts to authorize several cities to construct sanitary sewers and sewage disposal systems, to impose sewer service charges and to finance such construction by the issuance of sewer revenue bonds payable solely from such sewer service charges. For fear that the courts might possibly hold that the sewer service charges to be imposed under these special acts should be treated as special assessments, I provided in the acts for a public hearing on these service charges in substantially the same manner as in the case of special assessments.

I then prepared the ordinance for sewer revenue bonds in two of these cities. The conditions in the two cities are not the same. In one about ⅓ of the area, in which about ⅓ of the population live, had sewers, through which raw sewage flowed or was pumped into a bay in the city's front yard. These sewers had been paid for by general obligation bonds of the city, payable from taxes on all taxable property in the city and additionally secured by the proceeds of special assessments levied on the property abutting on the sewers. The new project involved the laying of additional sewers in the remaining populated sections of the city and the construction of a sewage disposal plant to treat and dispose of the sewage from the entire city. In setting up the financing program it was felt that it would not be equitable to impose the same charge on property which had already paid special assessments as on the property to be served by the new sewers. So provision was made for companion bond issues, one to cover the cost of the new sewer lines (collection system) and the other to cover the cost of the sewage disposal system, including the *intercepting* sewers, force mains, pumping stations, the treatment plant, etc. The first issue consisted of general obligation bonds payable from unlimited ad valorem taxes and additionally secured by special assessments (for about 60 per cent of the cost) on abutting property. This would place the property owners getting the new sewers on substantially the same basis as those who already had sewers and who had paid special assessments for a part of the cost of their sewers. The second issue consisted of unsecured sewer revenue bonds, payable solely from sewer service charges based on water consumption by the sewer user.

This plan of financing would place some burden on the owners of unimproved property in the new area, special assessments for the new sewer lines in front of such property and a tax to pay a part of the first issue of bonds. The second issue of bonds would be payable from equitable sewer service charges based on extent of use of the sewer in both the old and the new areas.

No One Plan Will Fit Every Case

The consulting engineers suggested that some charge be imposed on all unimproved property in the city in the nature of a "readiness to serve" charge on account of the fact that the construction of the system could be shown of benefit to all property in the city, whether improved or unimproved. But from the decisions of the courts up to that time, including the decisions of the Supreme Court of Pennsylvania in two Philadelphia cases, I feared that any such "readiness to serve" charge would be treated as an exercise of the taxing power, requiring an election on the issuance of the proposed bonds and also the inclusion of such bonds in computing the charter debt limit of the city.

In another city we now propose to include in the sewer revenue financing the cost of the sewer lines in the presently unsewered area and impose an "adjusted" service charge on the people in that area instead of a special assessment. It would appear from two decisions of the Supreme Court of that state that, if the proceeds of special assessments should be pledged to the bonds, it would be necessary to hold an election on the question of issuing the bonds. In another city, where the present sewers are entirely inadequate, many of them must be reconstructed and new sewers as well as a sewage disposal system constructed, the authorizing ordinance which was adopted last month makes a uniform sewer service charge on all users because of the extensive reconstruction required to place the existing sewers in good condition.

I have mentioned these different situations to show that there is *no one plan of financing which will fit every case.* The financing plan for each situation may have to be a tailor-made job and the working out or the setting up of each plan will involve a considerable amount of work and the closest cooperation on the part of the governing authority and its consulting engineers, bankers and lawyers.

Referring now to the three legal questions which have confronted us:

1—What are sewer service charges?
2—On what factors should the sewer service charges be based?
3—How shall the collection of delinquent charges be enforced?

What Are Sewer Service Charges?

In my opinion these questions are closely related and all of them have been convincingly answered by the Supreme Court of Florida in its opinion affirming the decree of the lower court validating a proposed issue of Sewer Revenue Bonds of the City of Miami, reported in 157 Fla. 726, 27 So. (2d) 118, and printed in full in *The Daily Bond Buyer* of August 5, 1946. I feel that this opinion is one of the greatest contributions in the field of municipal finance of any of the court decisions in recent years and that it will be relied on by the courts in other states as the leading decision on the subject.

Prior to preparing the brief in the Miami case, I read every decision on the subject which I could find and a great many articles, some prepared by leading engineers. Analyzing all this and drawing on my very limited knowledge of irrigation law in Montana, where I was engaged in general practice for a few years before getting into the municipal work in the Attorney General's office, I reached the conclusion that, fundamentally, sewer service charges are identical with water rates, that in reality they should be considered to be the second half of the water bill. In paying the water bill we do not pay for the water *itself* as we do for a ton of coal (or a bushel of potatoes) but for its *use*. As stated in my Florida brief,

> "In a modern city a waterworks system would be utterly useless without a system for the disposal of sewage. The service rendered by a waterworks system is only half of the complete service required. Through the waterworks system water which has been purified in accordance with standards prescribed by the proper health authorities is brought to the premises of the consumer for use. Through the sewer system the identical water, carrying the pollution resulting from its use in bathtubs, showers, sinks, washtubs and toilets, is taken from the premises and disposed of in accordance with standards prescribed by the same health authorities. For the service rendered by the waterworks system water rates or charges are imposed. For the service rendered by the sewer system sewer service rates or charges are imposed. The consumer does not pay for the water in either case but for its use, for the service rendered."

I relied to a great extent on recent decisions in New Hampshire, Pennsylvania and Arkansas. The Supreme Court of New Hampshire in Opinion of Justices (1944) 93 N. H. 478, 39 Atl. (2d) 765, had said "sewer rents imposed by the city of Concord are neither taxes nor assessments for a local benefit but, like water rates * * * are charges made for a service rendered." It was contended by the Attorney General that the principle of law which exempts the property of the State from taxation under general statutory provisions also precludes the imposition of a special assessment for improvements upon such property, but it was held that the charges of the city for sewer service are in no sense special assessments.

The City of Philadelphia was authorized by statute to charge and collect "annual rentals for the use of sewers, sewage systems and sewage treatment works," and such charges "shall be apportioned equitably among the properties served by the said sewer, sewage system, or sewage treatment works." In two decisions of the Court it was held that the ordinances passed by the City of Philadelphia did not comply with the statute because they imposed taxes and not charges for the use of the sewers. In the first case (In re Petition of the City of Philadelphia (1940) 340 Pa. 17, 16 Atl. (2d) 32) the ordinance was held invalid because the charge was made applicable not only to properties actually connected with and accommodated by the sewer system but also to vacant lots and properties not connected with the sewer system. In the second case (In re City of Philadelphia (1941) 343 Pa. 47, 21 Atl. (2d) 876) the rate imposed by the ordinance was a combination of two factors: (1) three mills upon each dollar of assessed valuation, and (2) 25 per cent of the water service charge, or water rent. The sewer rental rate based on assessed valuation of properties actually using the sewer system was held invalid as a tax measured by the value of properties served without relation to the use of the sewers.

In the third ordinance, which was sustained in Gericke v. City of Philadelphia (1945) 353 Pa. 60, 44 Atl. (2d) 233, the charge was "based upon the water consumption of the property served as measured by the charges for water supplied (water service) for the then current calendar year."

Only a short time before filing the brief, the Supreme Court of Arkansas in City of Harrison v. Braswell (1946) 209 Ark. 1094, 194 S.W. (2d) 12, sustained an issue of water and sewer revenue bonds of the City, payable solely from revenues of the municipal waterworks and sewer systems, saying:

> "A sanitary sewer system without water would be a total loss, and a water system without a sanitary sewer system would be impractical, if not entirely useless. So each complements or supplements the other."

In its decision in the Miami case the Florida Supreme Court held that the imposition of fees for the use of the sewage disposal system is not an exercise of the taxing power or the levy of a special assessment, saying:

> "A sewer system is complementary to a water system. A sewer system would be of no value without a water system and a water system would be entirely incomplete without a sewer system. So the principles of law which would apply to one system must likewise apply to the other."

Basis of Charges

Referring to the second question, the sewer service charges in the Miami ordinance were a certain percentage of the water bill, which in turn is based upon the quantity of water consumed as determined by meter measurement. This method appears to be the most equitable and was sustained by the Florida Supreme Court.

Collection of Delinquent Charges

As authorized by a provision we incorporated in the special legislative act, the Miami ordinance provided that the amount of the sewer service charges shall be actually included in the water bill, but each bill showing separately the amount of the sewer service charges and the amount of the bill for water, and that if the sewer service charges are not paid within thirty days from the rendition of the bill, the City shall discontinue furnishing water to the premises and shall disconnect the same from the waterworks system of the City.

In approving this method for the collection of delinquent sewer service charges, the Florida Supreme Court said:

> "Question Three is closely related to Question Two because it challenges the method provided for the enforcement of the charges for the use of the sewage disposal system * * *.
>
> "It is uniformly held that the City may cut off the water being furnished by the City to a consumer when such consumer fails to pay the water bill. * * *
>
> "It appears to us that if no constitutional rights of the owner or occupant of premises are violated by shutting off the water for non-payment of the water bill, no such right will be violated by shutting off the water for non-payment of the bill for use of the sewage disposal system, the two services being so interlocked that neither can be effective without the other."

In other words it becomes a case of "New and Used Water" as one water and sewage works manager has so aptly put it.

Forcing Connections with Sewer System

In cases where the premises of a substantial percentage of the population are using septic tanks and are not connected with the sewer system of the City, we have another problem. Is it lawful to include in the ordinance authorizing sewer revenue bonds a provision requiring the owners of such premises to connect with the sewer system and cease using their septic tanks?

If the construction of the sewage disposal system is to be financed by revenue bonds, payable solely from sewer service charges, a requirement to connect with the sewer system or else pay the charge in any event may be important. But if the construction is to be financed by general obligation bonds or if the statute authorizes, and the constitution of the state permits, the imposition of a readiness to serve charge on such premises, the financing may not be seriously affected.

In sustaining this provision in the Miami ordinance the Florida Supreme Court said:

> "The reasonableness or unreasonableness of the provisions of the section complained of must depend largely, and may depend entirely, upon the character of the terrain of the area affected * * *.
>
> "What may be considered an unreasonable requirement to be applied in a village located on the red clay hills of Leon County might be a regulation vitally necessary for the protection of the public health and welfare of the inhabitants of a city, the larger portion of the terrain of which is not more than 10 or 12 feet above sea level and a less distance above the average water table.
>
> "Private rights must always be subordinated to public rights and the public health is as sacred as any public rights can be. * * *"

Ownership of Water System Important

We have another problem in cases where the ownership and operation of the water system and the sewer system are not the same. Fortunately over 90 per cent of the urban population in this country is served by publicly owned water plants. But where a city or a substantial portion thereof is served by a water plant that is owned by a private corporation, can satisfactory arrangements be made with such corporation for computing and collecting the sewer service charges? Will it shut off the water for non-payment of such charges?

Where the pollution is caused by the sewage and wastes from several cities, towns and villages, we have still another problem. In some cities where I have been

working it is expected that the City will construct and operate the sewage disposal system and finance such construction by sewer revenue bonds of the City and then enter into contracts with the adjoining communities for treating their sewage. In some cases where there are several cities and towns, each owning its own sewer system and each being served by a separate water system, it will probably be necessary to enact legislation setting up a sanitary district or a sewer authority covering the entire territory. The preparation of such legislation will not be an easy task and working out the financing plan on an equitable base will be even more difficult if there are any privately owned water plants within the territory.

The Portland Water District as an Example

You may be anxious to have me make some suggestions in connection with your own situations, particularly here in Portland. But, as I have said, the financing plan for each situation must be a tailor-made job. The Portland Water District is a quasi-municipal corporation created by a special act of the Maine Legislature. The District supplies water to the City of Portland and several adjoining cities and towns. I understand that the City of Portland has its own system of sanitary sewers through which sewage flows untreated into the bays and waters surrounding the City, and that the pollution of these waters is now or may soon become a menace to the health of the inhabitants of the City. If this is true, it appears to me that it would be advisable for the City to have a thorough survey made of the situation, in the first instance by its own engineering, finance and legal departments and then, at the proper time, employ outstanding consultants, particularly consulting engineers who have specialized in this particular line, to cooperate in the preparation of a comprehensive plan for construction of sewage disposal works and the financing of such construction. In the preparation of such plan, consideration must be given to many matters, such as:

1—The type of treatment best suited to the situation, the design and location of the sewage treatment works, intercepting sewers, force mains, pumping stations, and other equipment, the cost of construction and the annual expenses of operation and maintenance.

2—The necessity from a health standpoint of constructing sanitary sewers in any unsewered areas.

3—The extent and the condition of the sewer facilities in the adjoining cities and towns and to what extent the sewage from these facilities contributes to the pollution to be abated.

4—If the construction of a sewage disposal system shall appear to be necessary, by what public instrumentality shall it be constructed and operated, and shall such construction be financed by general obligation bonds or revenue bonds? If all or substantially all of the area to be served is within the limits of the City of Portland, perhaps the City is the proper instrumentality. If so, in determining the type of bonds to be issued, consideration should be given to the margin between the present debt of the City and its legal debt limit and the necessity of preserving that margin for other public improvements.

But regardless of the ability or willingness of the City to issue its full faith and credit bonds, I would urge that careful consideration be given to the matter of issuing sewer revenue bonds, payable from sewer service charges to be imposed only upon those who actually use the system. If this plan should be adopted, however, who will collect the bills? The Portland Water District owns the water plant. Would it like to be a collection agency for the City? If so, how will it enforce collection, and will it be willing to shut off its own water for non-payment of the City's sewer service charges?

Perhaps the Water District is the proper instrumentality. It has done an excellent job in bringing pure water to the premises of those who use it. This, however, is only the first half of a complete service. The other half is the disposal of that water after it has been polluted by the user.

Reasonableness of Charges

Financing the construction of sewage disposal systems by the issuance of sewer revenue bonds, payable from sewer service charges added to the water bill, is comparatively new. There have been some objections to this type of financing on the grounds that the improvement is of general benefit to the community and should be paid for by a general ad valorem tax. I have no legal objection to this plan if the financial structure of the city or town will stand it. But it seems to me that real estate is carrying about all the load that it should at the present time. It is taxed for schools, police and fire protection and many other essential functions of government, both state and local, that cannot be financed in any other way. But in the case of many of our public facilities and utilities I believe that it is more equitable to require the users to pay for them.

What Will the Sewer Service Charges Amount To?

In an ordinance which I have recently prepared authorizing Water and Sewer Revenue Bonds to finance improvements of the City's waterworks system and also additional sanitary sewers and new sewage treatment facilities, the initial sewer service charges to pay the principal and interest of that amount of the bonds which are to be issued for the sewer improvements and to maintain and operate the complete sewer system after the construction of the improvements, will be 65 per cent of the water bill, after making proper adjustment for water not entering the sewer system, such as water used in the sprinkling of lawns, for air conditioning, steam production, etc. In another City for which I am working the sewer service charges will probably be as much as 100 per cent of the water bill.

Are such charges reasonable? Let us consider the service which is being rendered by a waterworks system and the service which will be rendered when the second half of the job is done.

The charge of the Portland Water District for delivering 1,500 cubic feet of pure water to the consumer is $2.50. A cubic foot of water weighs 62.3 pounds, 1,500 cubic feet weigh 93,450 pounds, almost 47 tons. In other words, the water user pays less than 6c a ton for water delivered into his home. What do you have to pay up here for a ton of coal or a ton of fuel oil delivered to your home? For the price of a pack of cigarettes you get three tons of pure water. On the basis of the sewer service charges I have just mentioned, you would pay from 4 to 6 cents a ton for taking away and cleaning up the water after you have fouled it.

It appears to me that such sewer service charges should not be considered unreasonable to the people in any community, particularly if they are fully advised through the press and public meetings how serious a menace to their health the present situation is and how small will be their individual contributions to remove this menace.

The people in a community never object to improving their water system in order to effect cheaper fire insurance. Why not provide some health insurance in addition?

For another valuable article on sewage works financing which discusses "Fundamental Considerations in Financing Sewage Works," includes a Model Sewer Revenue Ordinance, and presents methods of Billing and Collection of Sewer Service Charges, see pages R, 111-115 Reference & Data Issue of April 1951. Also see Report of Joint Committee on Rates and Rate Structures for Water and Sewage Works representing legal, financing, management and engineering interests in establishing charges for water and sewage service. Copies are available from the Ohio State Law Journal, Ohio State University, Columbus, Ohio, at seventy-five cents each.

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LLOYD D. KNAPP
Superintendent,
Bureau of Sewers, Milwaukee, Wis.

THE Bureau of Sewers designs, constructs, operates and maintains all combined, sanitary and storm sewers in the City of Milwaukee. All house sewers, from the main sewer to the building, are the property and responsibility of the property owner, and must be cleaned and maintained by him. The Milwaukee Sewerage Commission designs, constructs, operates and maintains intercepting sewers and a sewage treatment plant for the entire metropolitan area. The Commission was organized in 1913. Prior to that time all sewers in the City were of the combined type and emptied directly into one of the three rivers or into Lake Michigan.

Since 1915, the city has constructed separate sanitary and storm sewers in its newly annexed territories. Today the Bureau is responsible for approximately 500 miles of combined sewers, 300 miles of sanitary sewers and 300 miles of storm sewers. These sewers, most of which are circular, range in size from 6 in. to 144 in. diameter. Some of the storm sewers are of a rectangular section, the largest of which is a double box, with each side measuring 7 ft. by 10 ft.

The older sewers were built of clay pipe, natural cement concrete pipe and brick. The natural cement concrete pipe sewers were either 12 in. diameter circular, or egg-shaped 12 in. by 18 in., or 15 in. by 21 in., with a flat base to facilitate laying. Most of the older sewers 24 in. diameter or larger were built of brick, and in few instances of planks. Today vitrified clay pipe is used in sizes up to 36 in. diameter, concrete pipe in sizes up to 66 in. diameter, and monolithic concrete for box sections and circular sections as small as 48 in. diameter. Vitrified clay liner plates are used where needed in the monolithic sewers and in pipe sewers 42 in. diameter and over.

It is present policy to use concrete pipe for sanitary and combined sewers in residential and local business areas, and to use vitrified clay pipe in light manufacturing and industrial districts. Zoning is quite well stabilized, and this policy has proven satisfactory over a long period of years. The sewers are quite well ventilated and, since the establishment of the Sewerage Commission, designs have provided for minimum velocities of 2 ft. per second. There are, therefore, but few septic conditions, and there has been no known trouble with hydrogen sulfide gas in the residential areas.

Organization

The Bureau of Sewers is organized into a construction division, an engineering or design division, an accounting division, and a maintenance diivsion. This latter division is in charge of the cleaning, flushing and repair of all sewers and appurtenances, as well as the construction of all catch basins, storm inlets and overflows. The division is under the direct charge of a field supervisor and an assistant. The city is divided into three districts, each under the supervision of a district foreman reporting to the field supervisor. Each district foreman is in charge of two or three construction gangs, consisting of a foreman with eight or ten men, a catch basin cleaning crew, one or two sewer cleaning gangs, a flushing crew, one or two sewer masons with helpers, a troubleman, and a timekeeper. At division headquarters there is a blacksmith, a carpenter, and a machinist, all with helpers, and two sewer examining crews of three men each.

All city-owned automotive equipment, such as automobiles, trucks, trailers, air compressors, eductors, concrete mixers, cranes, etc., are operated and maintained by the Bureau of Municipal Equipment. This equipment is rented to the various other bureaus as needed and at rates somewhat below that charged by private owners. Special equipment such as pumps, cleaning machines, steamers, etc., are in direct charge of the Bureau of Sewers.

Construction Crews

The construction crews excavate for the catch basins, and construct storm inlets and overflows during the construction seasons. These crews also build short sections of new sewers as the occasion may require.

Catch basin and manhole bottoms are poured with ready-mixed concrete and, where conditions permit, steel forms are set up and the bottom half of the catch basin is also poured with ready-mixed concrete. A sandbag is placed in the form to provide an opening for the overflow pipe and trap. A sewer mason follows this crew and lays up the top half of the catch basin with concrete brick.

The storm inlet assembly consists of a frame and grate with a side inlet box resting on a layer of brick. The brick rests on the edge of a large cast iron bowl, and the bowl in turn rests on a cast iron elbow with a 15-in. radius. The elbow has a large flat base to facilitate placement, and after it has been set and backfilled with gravel, the rest of the assembly is quickly put together. The frames, grates, and side inlet boxes used in storm inlet construction are identical with the castings used for catch basins.

Each crew has a combination tool wagon and shanty equipped with a small stove. Each crew is assigned an air compressor with sufficient capacity to operate two jack hammers continuously. The city owns both trailer-mounted and truck-mounted compressors and an effort is made to keep one truck-mounted compressor in each district for emergency use. The older compressors are mostly Sullivan or Ingersoll Rand, while the newer machines are LeRoi. Each crew also has two jack hammers, two clay diggers, and a demolition tool. This latter tool is a small compact rig that can be used inside a catch basin or manhole for tearing out masonry work. These pneumatic tools are of various makes such as Sullivan, Cleveland, Ingersoll Rand, and Chicago Pneumatic. All of the pneumatic equipment has proven satisfactory.

Each construction crew also has a 1½-in. C. H. & E. centrifugal pump, two wheelbarrows, screw jacks, 200 ft. of 2½-in. flushing hose, 100 ft. of 1-in. flushing hose, a hydrant valve, barricades, red flags, lanterns, and miscellaneous small tools. These special hydrant valves are used to regulate the flow of water, thus permitting the hydrant itself to be open to full capacity. The Water Department recommends this practice as a means of preventing wear and tear on the hydrant parts.

The city owns one truck-mounted Hydro-crane with a ¼-cu. yd. bucket, which the Bureau of Sewers uses on a year-around basis. One or two more of these cranes are rented during the construction season. These cranes are operated hydraulically, even to the opening and closing of the bucket. They are used for digging purposes, and they operate quite successfully where the ground is not too hard.

The advantages of this type of machine are that it can be quickly moved from place to place in an emergency and can be digging 2 or 3 minutes after arrival on the job. The machine is mounted on an International Truck chassis and can travel

Le Roi 105-160 Cu. Ft. Per Min. Two Stage Compressor Mounted on International Truck.

*Reprinted from Sew. Wks. Jour., Vol. 21, p. 475 by permission.

Sewer Cleaning Machine With Self-Closing Bucket Manufactured by Turbine Sewer Machine. Co.

along city streets safely at a speed of 25 to 30 miles per hour. This equipment is used to greatest advantage in the outskirts where there is little interference from other underground structures. One 2½-cu. yd. dump truck accompanies each Hydro-crane. This is sufficient, especially in the outskirts where a dump can usually be found within a 5- or 10-minute run. These cranes are also used in the older sections of the city, at locations where digging conditions are favorable. Experience with the Hydro-cranes to date indicates that under favorable conditions the cost of excavation can be reduced approximately 30 per cent over hand digging.

Otherwise all digging for catch basin and overflow construction as well as for sewer repairs is done by hand. The hand digging crews load their dirt into trailers of about 5 cu. yd. capacity. The empties are spotted and loads pulled once a day.

In the winter months the construction crews are put out on repair jobs. They remove and replace broken or cracked pipe, break out and replace defective concrete in tunnels, and break out defective masonry in the brick sewers preparatory to repairs to be made by the sewer masons. One extensive repair job carried over several winter seasons, involving the removal and replacement of concrete in the lower quadrant of a 72-in. tunnel and the lining of same with vitrified clay liner plates. This was a storm sewer tunnel into which acid had been discharged for several years. Winter digging is admittedly expensive, but it has been necessary to operate all winter in order to keep the crews manned with experienced men, and because it is not possible to hire sufficient men to make the necessary repairs in the summer months when the construction program is heavy. Then too, it would be difficult to secure the extra tools and equipment needed to do both repairs and construction in the summer.

The city of Milwaukee for years has had an Accident Prevention Committee composed of key representatives of the various operating departments. The field supervisor is the representative for the Bureau. This committee has done much to promote safety among city employees. Supervisory forces make it a point to instruct new men in the use of tools, to examine tools for defects, etc. Supervisors are especially particular in the bracing and shoring of trenches and tunnel sections. Men are not permitted to work in the so-called "rat hole" sections. As a result of these precautions the usual accidents are of a minor nature. There have been no accidents due to cave-ins for many years.

Sewer Cleaning

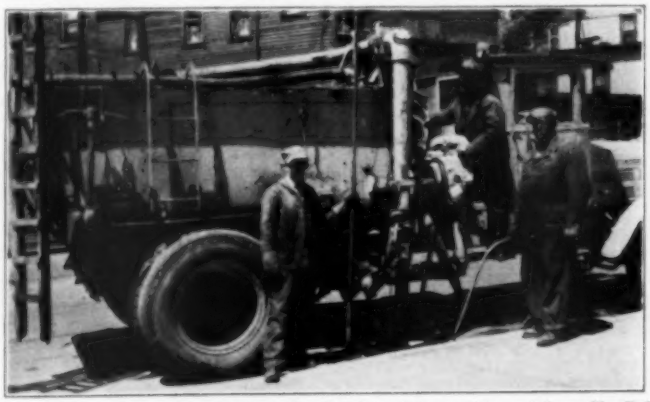
There are four sewer cleaning crews of three men each. One crew is using a pair of Champion 7.5-h.p. machines; while two crews are using a pair of Sewer Turbine 7.5-h.p. machines. One crew has a pair of 3-h.p. Sewer Turbine machines. The smaller machines are used on the smaller sewers so as not to overload the motors. All of the machines are proving satisfactory. However, the level winding apparatus was removed from the Champion machines and substituted by a loose pulley. The gearing on the Turbine machines was also changed so as to increase the cable speed from 33 to 90 ft. per minute. Self-closing buckets are used in sizes from 6 in. to 18 in., made by the Champion Company. Some plain buckets or scoops have been made up to fit several different sizes of small egg-shaped sewers, and circular scoops have been made for sewers 21 in. diameter or larger.

Elm strips ½ in. by 2 in. and of varying lengths up to 10 or 12 ft. are used in getting the pilot cables through the sewer. These strips are notched at the ends and fastened together with wire. They are quite flexible and can be readily shoved through the sewer. Any water in the sewer, of course, will cause the strips to float and facilitates their use. If the normal flow in the sewer is not sufficient to float the strips it is an easy matter to connect a hose to the nearest hydrant and obtain the amount of water desired. Jointed, wooden sewer rods about 1½ in. square and in 3-ft. lengths are used for the same purpose. When neither the elm strips or rods will work, a Flexible sewer rod is put through and the pilot cable pulled back when the rod is withdrawn.

Sewers under busy streets or car tracks are cleaned at night. When cleaning along car tracks, hand cleaning rigs are employed, as these can be shoved aside more readily than the power machines in order to let street cars pass.

Flushing

Four flushing crews of three men each are maintained. Each crew is equipped with about 500 ft. of 2½-in. hose, one 8-in. and one 12-in. flushing bag, a wheelbarrow, manhole guards and various small tools. During the winter a stiff rubber coated hose is used, from which the water can be drained and which will not freeze up during severe cold. In the warmer months discarded fire hose is employed, which is bought from the Fire Department for 10 cents a foot. One length of the rubber covered hose is shoved down the manhole and into the sewer because of ease of handling. Hose bridges are made by a carpenter and consist of cham-



Elgin Eductor Mounted on Sterling Chassis—Note Agitator Pipe and Long Handled Rake for Cleaning Out Sticks.

fered 3-in. planks fastened together with steel bands. Discarded rubber hose is cut up and nailed on the bottom of the planks and this prevents skidding of the hose bridge under impact of even heavy vehicles, provided they travel at moderate speed. During 1947, 262 miles of sewers were flushed.

All storm inlets are flushed once a year by these same crews. There is a considerable waste of time in coupling up hose to the nearest hydrant, setting the hose bridges, etc., only to find that one good shot of water is all that is needed. The field supervisor is now studying the possibilities of using power flushers for this work.

Catch Basin Cleaning

Catch basins are cleaned once a year. This work is carried out by two catch basin cleaning crews, each consisting of a foreman and eight to ten men. Each crew has three or four Elgin eductors, a 1½-ton truck, a wheelbarrow, a small centrifugal pump and various miscellaneous tools. Each educator crew will clean an average of twenty catch basins per day. The truck and two men are used to clean, by hand, those basins which are inaccessible to the eductors, and to finish cleaning those basins which cannot be properly cleaned by the eductors. Each eductor crew carries a garden rake for removing sticks, branches, etc. They frequently find chunks of broken concrete or other material which cannot be removed either by the eductor or by the rake, and the extra cleaning is then taken care of by this manual cleaning gang. The eductors are over 20 years old and are in need of replacement. It is hoped soon to inaugurate a program of modern equipment replacements.

The eductors operate about 8 months of the year, which is about all that weather conditions will permit. During the winter months the crews do hand cleaning of catch basins.

Last year 19,262 catch basins were cleaned by eductor and 5,099 by hand. Admittedly hand cleaning is more expensive, but there will always be many catch basins that cannot be cleaned with the present equipment. And, invariably, either weather conditions or appropriations for equipment rental will interfere before the complete rounds can be made of all catch basin cleaning work. There are approximately 25,000 catch basins and 15,000 storm inlets. The inlets are taken care of, as previously mentioned, by the flushing crews.

Bucyrus-Erie H-2 Hydrocrane Mounted on International Truck Chassis with Orange Peel Bucket for Cleaning Catch Basins.—(This practice is new since the article was written.)

The foreman is furnished with blue line prints of quarter-sections showing the location of all catch basins and storm inlets. He returns these maps to headquarters showing the date of cleaning and notes as to the structural condition of the basins.

Sewer Troublemen

Each district has a sewer troubleman who drives a pick-up truck. His duty is to investigate all complaints in his district. These complaints cover a wide range of subjects, from water standing in the gutter to a leaking kitchen faucet; from rats crawling out of plumbing fixtures to rubber balls lodged in downspouts. In most cases the Bureau of Sewers is not involved, but the troubleman will give the best advice of which he is capable.

The troubleman opens up blocked sewers and catch basins, calling on the nearest labor gang for help. A troubleman and two laborers are on duty every Saturday, Sunday and holiday to handle emergency calls and one of the troublemen is always subject to call by the City Hall night complaint clerk.

During storms, when hundreds of complaints may come in, various foremen and some of the better class laborers are used on trouble shooting service. At such times the maximum number of crews are operated that can be provided with transportation. These forces stay on the job until every complaint has been investigated. In some instances this has taken as many as 36 hours of continuous operation.

Troublemen are also employed during slack periods with the delivery of small orders of materials for construction crews and the moving of the flushing crews and brickmasons from job to job. They also answers complaints on loose manhole covers. If the cover and frame are found to be in reasonably good condition the cover is sealed in place with Hallemite, which has been giving us good service. All flushing crews carry a small supply of this compound.

Hough End Loader Used for Cleaning Up Jobs and Loading Hand Excavated Material. (This practice is new since the article was written.)

Cleaver-Brooks Oil Burning Steamer for Thawing Out Frozen Catch Basins, Storm Inlets and Culverts.

Sewer Inspection Crews

There are two sewer examining crews consisting of a foreman and two men each. These crews have trained personnel and special equipment, and have regular programs for examining sewers as to structural conditions, amount of flow, depth of deposit, etc. Many sewers are flushed or cleaned in accordance with the information obtained from these reports. When a street is to be repaved, an examining crew inspects the sewers, and the designers use their report to determine the necessity of rebuilding the sewer because of its structural condition.

These crews are used for many types of work. They examine all contract work, upon completion, and discover many defects overlooked by the inspector, or which could not be determined by the inspector working alone. They are used frequently in tracing out the point at which given house services and overflows are connected to the sewer. They check for highwater marks in manholes following storms, and occasionally they make house to house surveys to determine the extent of backwater conditions.

These crews are so valuable that their services are in constant demand by the construction forces, engineering division and also by district foremen. It is difficult to keep them at their primary task of examining sewers on a routine basis.

Examinations of the smaller sewers are made by means of flashlights and mirrors. The men crawl or walk through all sewers 30 in. in diameter or larger, flow conditions permitting, and occasionally crawl through 24-in. sewers.

Each crew has a safety belt for use in deep manholes, rubber coats, hats and boots for ordinary work and rubber suits for very wet, dirty work. They also carry a Wolff safety lamp, aluminum ladders for use where manhole steps are unsafe or missing, a small quantity of potassium permanganate, and a considerable number of small tools and supplies.

Sewer Masons

There are four sewer masons, each with two helpers, who work the year around. During the construction season, when the new catch basin work required in connection with new paving is the heaviest, two or three more mason crews are added to build basins and to set basins and manhole frames to final grade. Because of past budget restrictions it has been necessary to impose on some of the more skilled laborers to do this work without extra pay. This past summer, however, it was possible to obtain for three of the best men the regular sewer mason pay for a period of a few months. A plan is now in development to pay four of the best men a rate $15 per month above that of common labor. These men will be used normally as leading helpers to a sewer mason. In the rush seasons they will be used for setting manholes and catch basins to grade, thus relieving the regular masons for the more skilled work of building manholes and catch basins.

There are more brick repairs than can be handled with the four regular masons during the off season. There are perhaps 25,000 catch basins and approximately 40,000 manholes, most of which are built of brick and many of which need repairs, as well as many, many miles of brick sewers which need more and more repair work as they become older.

At the present time the mason crews have only a small tool box, but a program is planned to equip all crews with a small combination tool wagon and shanty.

Yards

At the district yards there is a supply of special tools and equipment as needed, such as centrifugal pumps up to 4-in. discharge, 4-in. Pemberthy syphon pumps, three Homelite blowers operated by gas engines, two electrically operated blowers, three 1500-watt portable light plants, and a Cleaver Brooks oil-burning steamer for thawing out frozen catch basins. There are small derricks and two hoists operated by compressed air and two operated by gas engines, also flumes of various sizes, rock drills, and cutting and welding equipment. In addition there are three Flexible sewer rod outfits which are used in opening up blocked sewers and Coleman rods for use in checking clogged house sewers.

The clerical forces keep time and material records, order materials and equipment, keep a card index file of complaints by house numbers, type the reports of the examining crews, tabulate the records of cleaning, flushing, etc. Ready-mix concrete, backfill gravel, brick and pipe are purchased on open order and may be secured as needed from the vendor, who delivers directly to the job.

In all there are 160 people in the operation and repair division, which includes all classes from laborers and clerks on up to the field supervisor. Common laborers are known as "city laborers" and do sewer cleaning and flushing and catch basin cleaning. They receive a top pay of $140 per month, plus a cost of living bonus of $83.02 per month. The laborers on construction crews are called "sewer laborers" and receive a top pay of $150 per month, plus the cost of living bonus. Sewer examiners get $165 per month, their foreman and the troublemen get $180 per month, while the construction crew foremen receive $210 per month, all with the cost of living bonus in addition. The highest, of course, is received by the field supervisor, who gets $350 per month and the bonus. The total budget for operation and repairs for 1948 amounted to $529,459, approximately $480 per mile.

Typical Flushing Crew—Note Regulating Valve Which Permits Hydrant to be Open to Full Capacity.

Fairbanks-Morse 4-in. Centrifugal Woods Trash Pump with 20 hp. Le Roi Motor.—(Capacity 70,000 gph. Used for pumping out sewers, basements, flooded areas, etc.)

Discussion

Francis S. Friel
President,
Albright and Friel, Inc., Con. Engrs.,
Philadelphia, Pa.

Mr. Knapp has given an excellent outline of the scope of the organization, equipment and maintenance procedures of the Milwaukee Bureau of Sewers.

In Mr. Knapp's remarks relating to sewer construction he reports that all house sewers from the main sewer to the building are the responsibility of the property owner and must be cleaned and maintained by him. This same practice prevails in the Philadephia area. Prior to the war, one suburban area outside of Philadelphia made house connections through contract, within the bed of the street, and charged the property owners a fixed sum for it. This practice has been stopped because of present labor conditions, and now property owners are required to engage their own contractors who, in turn, must be bonded by the municipality.

Reference is made to the practice in Milwaukee of using vitrified clay pipe for sewer lines up to 36 in. in diameter; concrete pipe up to 66 in. in diameter and monolithic concrete structures with vitrified clay liner plates where needed. It is also interesting to observe that it is the policy in Milwaukee to use concrete pipe for sanitary and combined sewers in residential and local business areas, and to use vitrified clay pipe in light manufacturing and industrial districts. This practice is commended.

Mr. Knapp does not mention any difficulty experienced in locating manholes or other sewer structures. Manholes are often covered with new paving or by grading of private property or regrading of roads, and instruments to locate them are invaluable in time-saving. Magnetic dip needles are convenient for shallow depths, while the "M-scope" is required for deeper coverage.

The use of the sewer examining crews for inspection of new construction and for periodic examination of lines is good practice. The best insurance against excessive maintenance is a well-designed and well-constructed sewer line. A small municipality in Pennsylvania installed a sewer system about 25 years ago. The sewers were poorly constructed due to a lack of proper inspection. Since the original construction, more than twice the first cost has been spent by the town and by W.P.A. in attempting to repair the sewer lines. In some instances, a pipe between two manholes, located less than 300 ft. apart was out of alignment as much as 3 feet. In addition, the system leaked badly. The unsatisfactory conditions in this sanitary sewer system have not been corrected and a large expenditure is still necessary to complete the rectification of the original unsatisfactory work. Money spent for good engineering and inspection pays dividends on future maintenance.

The disintegration of sewers, as indicated by the need for a retreading job on a 72-in. sewer noted in Mr. Knapp's paper, once again illustrates the need and justification for regulation of the disposal of industrial wastes, taking into account the character as well as the volume of the wastes to be handled. In some cities, surveys have been made to eliminate the discharge of industrial wastes, particularly strong acids, which might cause the disintegration of sewer lines. It is certainly logical to require a particular industry to neutralize strong wastes prior to their discharge to a sewer system.

The frequency of cleaning of a sewer line is dictated by the character of sewage, the flatness of the sewer grades, the condition of the pipes themselves and also possibly by weather and climatic conditions. No hard and fast rule can be applied as to the interval between the cleaning of a sewer. In Lower Merion Township, Pa., the sewers are flushed once a year. The conditions observed during the flushing period form the basis of a priority maintenance program. All free time of the maintenance crew is used in a systematic cleaning of the 142 miles of sewers. Six years are required for the complete coverage cycle. A force of four men with one truck and up-to-date cleaning equipment does the job. The superintendent reported recently that only three stoppage complaints have been received in five years.

There are some instances where sewers have never been cleaned since they were installed. On the other hand, certain sewers have clogged in a relatively short period of time due to the growth of tree roots and other external causes.

The use of a flexible steel type of sewer rod to clean sewers has proved advantageous in many places throughout the country. This type of equipment may be used to remove obstructions which cannot be dislodged by a wooden rod. It is especially effective where fire plugs may not be available and when extra flushing

Bucyrus-Erie H-3 Hydrocrane Mounted on International Truck Chassis—Clam Shell Bucket for Excavating Work.

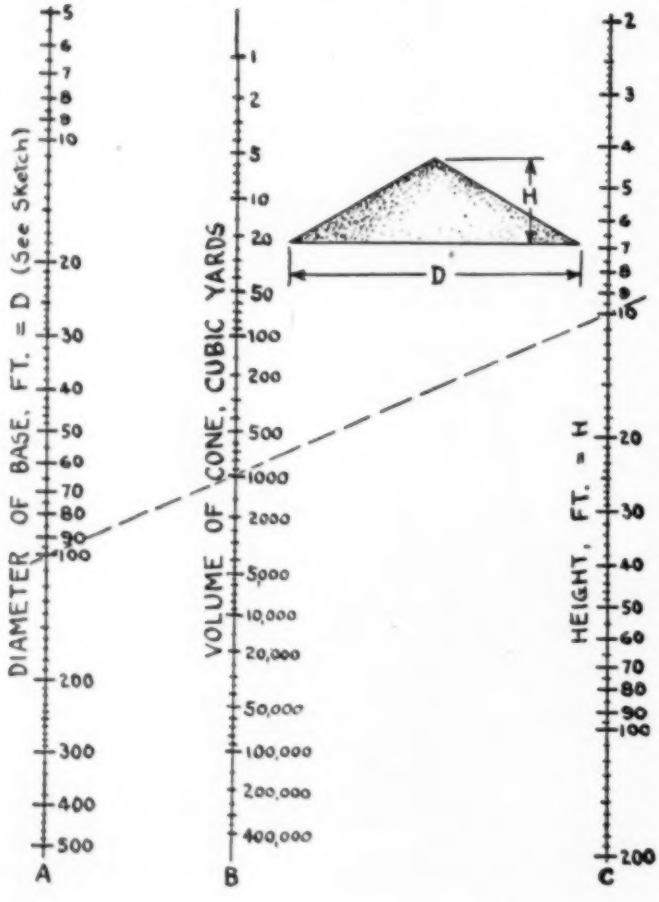
water must be hauled to the work. There also is a safety factor involved in using flexible steel rods, since the men are working above ground.

The mechanical cleaning at Milwaukee is apparently by the drag-line type of cleaner. This type of apparatus is effective but is inclined to cut tracks in deposits where flows are small. The water-driven turbine type will do its work well, but the writer does not believe that this latter type of equipment is equal to the revolving spring-steel rod utilizing different kinds of cleaning or cutting heads, and the rubber cups for removing sand or other deposits when backed by a head of sewage.

Flexible sewer rods and machines were found to be valuable cleaners at Boston (*American City*, August, 1942). At Los Angeles, Brown states that nearly one and one-half million feet of sewer lines are cleaned each year with three machines, and the cost of upkeep and personnel was 3½ cents per foot of sewer pipe cleaned. Mr. Brown states that each machine may be set up at 10 to 20 locations a day and can clean from 1500 to 2500 ft. of sewer line daily (*Water and Sewage Works*, p. 249, 1947).

Catch basins at Milwaukee are cleaned once each year. This practice varies throughout the country. In some places they are cleaned as often as once every 3 months, while in other instances the period of cleaning is extended to about once in 3 years, as in Boston. The eductor type of catch basin cleaning apparatus as mentioned for Milwaukee is most effective, and reduces the unit cost for the removal of grit and other foreign material.

In most municipalities, where the water works is owned by the city, there is no problem in securing water for flushing sewers, but where a private company owns the water works, the problem differs materially. Again citing the case of Lower Merion Township, it is cheaper to use creek water for flushing than to purchase water from the private utility. The township, which has an area of 24 sq. mi., has a 700-gal. tank mounted upon a 2½-ton truck, and water is pumped to this tank from a series of creeks or taken from one of the twelve fire hydrants permitted to be used. The tank is equipped with a quick-opening valve, and the contents are discharged rapidly to a manhole for flushing.



CONTENTS OF CONICAL PILES*

Frequently it becomes desirable or necessary to estimate yardage in a pile of dirt, sand, stone, gravel, coal, etc.

Without any figuring whatever the accompanying chart quickly gives the number of cubic yards in any conical pile.

For example, how many cubic yards in a conical pile whose based diameter is 100 ft. and whose height is 10 ft.?

The dotted line drawn across the chart shows how it is done. Run the line through the 100 ft. diameter, column A, and the 10 ft. height, Column C, and the intersection with column B gives the answer as a little less than 1000 cubic yards.

The range of the chart takes care of all diameters from 5 to 500 ft. and all heights from 2 to 200 ft. However, in the event that diameters or heights should be greater or less the same chart is still applicable. Thus if the diameter should be 1000 ft. instead of 100 ft. and if the height should be 100 ft. instead of 10 ft., the same dotted line would solve the problem excepting that the answer would be 1,000,000 cubic yards instead of 1000 cubic yards. In that case the rule is this: For every cipher added to column A, add two ciphers to the answer in column B, and for every cipher added to column C, add one cipher to the answer in column B. This means that when the problem is 1000 ft. diameter and 100 ft. height, three ciphers must be added to the result in column B.

*Contributed by W. F. Schaphorst, M.E.

DOSAGE CONTROL IN SEWAGE CHLORINATION

By GEORGE E. SYMONS
Formerly, Managing Editor Water & Sewage Works
Presently, Consultant and Technical Editor,
Larchmont, N.Y.

IN SEWAGE treatment works employing disinfection by chlorination, some control of chlorine dosage is necessary to meet the varying needs. The larger the plant the more important is such control, both from the standpoint of economy and bactericidal efficiencies. Efficient and non-wasteful usage is important and there is particular merit in efficient application control in the sanitary field.

Quite obviously, any system of continuous chlorine dosage control to meet variable conditions will produce the most efficient results[1]. Lacking continuous control, some "programmed step by step method of chlorination"[2] offers the best substitute. The time interval of the steps may be dictated by the size of the treatment works, the variables of chlorine demand and flow, the plant personnel and operation routine, the desired results, and the economy involved. The effect of all these factors must be considered in the development of the control system.

A Control System

In the development of a control system, it is necessary to set up certain definitions, techniques, dosage curves, control tests, and factors. These are essential to meet all possible variations of chlorine demand by hours or seasons, and with temperature and storms and industrial wastes as well as with pumping schedules and other operating conditions.

Definitions

Chlorine Demand: The parts per million (mg. per liter) of chlorine required to be added as *chlorine water* (1 mg. Cl_2 per ml.) to produce 0.1 p.p.m. of residual chlorine after 15 minutes contact of the chlorine water and sewage.

Residual Chlorine: That chlorine added to water or sewage which is available, after a definite contact time, for reaction with orthotolidine or potassium iodide. It is the surplus of chlorine added which is not required in satisfying the chlorine demand of the liquid chlorinated.

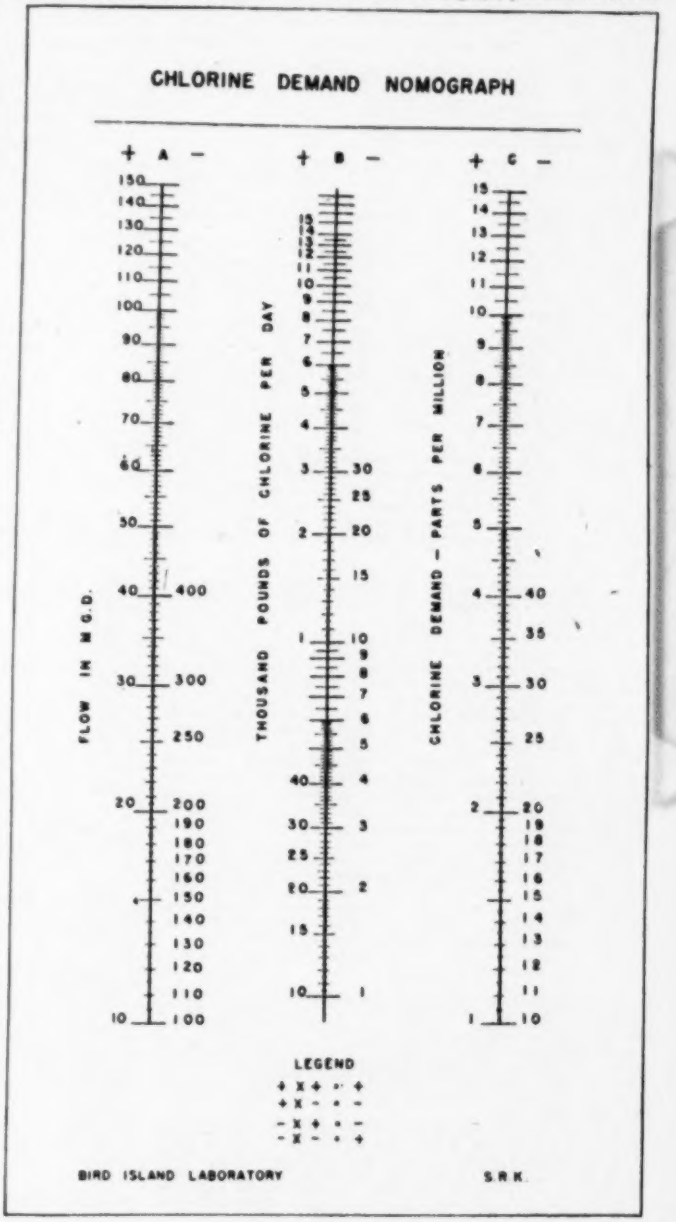
Spot Test: The determination of the residual chlorine in chlorinated liquids by the addition of 3 drops of orthotolidine reagent to 1 ml. of sample on a conventional laboratory spot plate.

Immediate Chlorine Demand (I.C.D.): The parts per million (mg. per liter) of chlorine required to be added as chlorine water (1 mg. Cl_2 per ml.) to produce 0.1 p.p.m. of residual chlorine when a spot test is made on the sewage immediately after the addition of the standard chlorine water. This value is indicated by the abbreviation I.C.D.

Reagent Factor: The factor used to calculate p.p.m. of chlorine demand from the amount of chlorine water added to the sample. This factor is calculated from the size of the sample (in ml.) used for the determination, and the strength of the chlorine water in mg. per ml. Reagent factor × ml. of chlorine water = p.p.m. of chlorine demand (C.D.).

Chlorine Demand Rate per 24 Hours: The feeding rate, in terms of pounds of chlorine added per day, required to satisfy the chlorine demand of any given flow of sewage with a particular chlorine demand, i.e., the rate of feed required in lb./24 hrs. to meet the chlorine requirement for the flow and sewage strength (chlorine demand) existing at any hour.

Chlorine demand rates per day equal p.p.m. of C.D. × flow in m.g.d. × 8.34. This value can be determined directly from the Multiple Chlorine Demand Nomograph, published in the No-



vember, 1940, issue of this magazine[5]. It is an adaptation of a single nomograph for chlorine demand originally developed by Everett C. Handorf[6].

Chlorine Demand in Pounds per m.g.: Lb. per m.g. = p.p.m. of C.D. × 8.34

Dosage Factor: The factor by which the chlorine demand (lbs. per m.g.) at any particular hour must be multiplied to determine the chlorine dosage rate (lb. per m.g.) for the following hour.

The use of this factor may be necessary in the control of the chlorine dosage because frequently the time required for collecting the samples and making the chlorine demand test makes it impossible to ascertain the demand until after the sewage represented by the sample has been chlorinated. This factor is affected by the time of day, season of the year (temperature of sewage) and storm flows.

Dosage Rates: The number of pounds of chlorine to be added to each million gallons of sewage pumped during the succeeding period until another adjustment is made.

The Determination of Chlorine Demand

Approximately a 5 pint sample of sewage is collected. All samples should be delivered immediately to the laboratory for analysis. Residual chlorine tests should be made on samples of sewage after chlorination. The chlorine demand is determined on samples, as follows:

(1) *Reagents:* Chlorine water made by passing chlorine gas through distilled water or tap water until 1 ml. contains approximately 1 mg. of chlorine. Standardize by titration with thiosulphate. Orthotolidine indicator solutions as recommended in the committee report on "Control of Chlorination"[7].

(2) *Procedure:* Measure out 5 portions of sewage to be tested, using 200 to 250 ml. samples. To the first of these samples add the standard chlorine water, 0.5 ml. at a time (equivalent to approximately 2 p.p.m. of chlorine) mixing by gentle agitation until a spot plate test, using 3 drops of orthotolidine solution and 1 ml. of the sample, give a detectable yellow color[8], but not necessarily a non-fading color. Call this the immediate chlorine demand (I.C.D.).

Using the I.C.D. as the basis of dosage, add reagent chlorine water to the other flasks in increasing quantities, using increments of 0.2 to 0.5 ml. above the I.C.D. Gently mix the contents of all flasks and allow to stand for exactly 15 minutes. At that time determine the residual chlorine in each flask by a spot test. (It may generally be expected that the I.C.D. is somewhat less than the 15 min. C.D.)

Usually 1 minute is sufficient for the development of maximum colors. Use standards made from chlorine water or permanent standards made from copper sulphate and potassium dichromate solutions. These latter must, however, be adjusted to match the hue produced by chlorine water and orthotolidine in a spot plate.

When the maximum color has developed in all spots determine the dosage which has produced 0.1 p.p.m. of residual chlorine or thereabouts. In the absence of standards for comparison, pick the spot with the minimum color. This color is approximately 0.1 p.p.m. In some cases it may be necessary to interpolate in order to determine the amount of chlorine reagent necessary to produce the readable color.

(3) *Calculations:* Calculate the chlorine demand from the amount of chlorine water used and the reagent factor, as illustrated previously. When using 250 ml. of sample; ml. of chlorine solution × mg. of chlorine per ml. × 4 equals p.p.m. chlorine demand (C.D.), or prepared tables may be used for different sized samples and different reagent factors.

For the data records the Chlorine Demand Rate in pounds per 24 hours is determined from the chlorine demand in p.p.m. and the registered sewage flow at the time of the sampling. The Chlorine Demand Nomograph[9] (see cut) is used for this calculation and the resulting value is utilized in weighting the 24 hour average chlorine demand in parts per million.

Directions for Using the Nomograph

In reading the nomograph to determine the chlorine demand or dosage in 1,000 pounds per day from the p.p.m. and the flow in m.g.d., a simple algebraic rule for multiplication must be remembered, viz., plus times plus equals plus, plus times minus equals minus, and vice versa, and minus times minus equals plus. Therefore, if the A+ and C+ scales are used, read on B+, or if A+ and C— are used, read on B—, or if A— and C— scales are used, read B+.

The use of these scales in this manner allows a range of from 1 part per million and 1,500 m.g.d. to 150 p.p.m. and 10 m.g.d. with the thousand pounds per day varying between 0.1 and 1,500. Factors or multiples of 10 extend the range in both directions. By the use of factors or multiples, the readings can always be kept in the area most easily read. A factor of 1,000 will easily convert thousand pounds per day to pounds per day. Scales "A" and "C" can be used for quantities rather than rates per day, in which case Scale "B" reads in quantities rather than rates per day.

The nomograph has other applications than in chlorine application. It may be used to calculate pounds or thousand pounds of solids in sewage, or sludge, from the analysis and the volume, and for other purposes.

This type of nomograph has several advantages, its use is simple, it gives relatively accurate readings, its system and use can be easily taught to routine control, and it eliminates much calculation where the chlorine demand determination is made frequently.

Determination of Chlorine Dosage

After the determination of the chlorine demand on the samples, the results must be translated into operation control. The data available for this use include the following:

a. The 15-minute chlorine demand of the raw sewage.

b. The residual chlorine or chlorine demand (as the case may be) of a sample of sewage after chlorination.

Obviously all of these data represent conditions that have passed and therefore some relation between such data and future hours has to be developed. The average or normal expected relation of the chlorine demand of one hour to the next for raw sewage may be determined from statistical study of the hourly variations in chlorine demand[6]. Inasmuch as these relations vary with seasonal temperatures, it is necessary to develop several series of factors to apply at the different seasons. Typical factors as developed at Buffalo, N. Y.,[3] are listed in Table I which shows the percentage by which the chlorine demand of the previous hour must be multiplied to obtain the chlorine demand for the hour desired. For practical purposes these percentages were rounded off to factors containing one decimal place as shown.

If there were no other factors involved, it would be possible to calculate the *Chlorine Dosage Rate* in pounds per million gallons for the succeeding hours from these factors and the chlorine demand in p.p.m. of the sample of the previous hour. However, it has been found in practice that there is a seasonal empirical factor that must be applied to these calculations. In the winter time it is found that something less than the calculated

TABLE I

FACTORS FOR DETERMINING CHLORINE DEMAND AT ANY HOUR FROM RESULTS OF PREVIOUS HOUR

Season	Jan. Feb. Mar.		April		May		June July Aug. Sept.		Oct. Nov. Dec.	
Hour	Per Cent	Factor	Per Cent	Factor	Per Cent	Factor	Per Cent	Factor	Per Cent	Factor
8:00 A.M.	90	0.9	90	0.9	100	1.0	110	1.1	120	1.2
9:00 A.M.	100	1.0	100	1.0	110	1.1	110	1.1	110	1.1
10:00 A.M.	110	1.1	110	1.1	120	1.2	120	1.2	120	1.2
11:00 A.M.	110	1.1	110	1.1	110	1.1	120	1.2	130	1.3
12:00 Noon	100	1.0	100	1.0	110	1.1	110	1.1	120	1.2
1:00 P.M.	90	0.9	90	0.9	90	0.9	100	1.0	110	1.1
2:00 P.M.	80	0.8	80	0.8	80	0.8	90	0.9	100	1.0
3:00 P.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
4:00 P.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
5:00 P.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
6:00 P.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
7:00 P.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
8:00 P.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
9:00 P.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
10:00 P.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
11:00 P.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
12:00 Mid.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
1:00 A.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
2:00 A.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
3:00 A.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
4:00 A.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
5:00 A.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
6:00 A.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0
7:00 A.M.	70	0.7	80	0.8	80	0.8	90	0.9	100	1.0

chlorine dosage from laboratory tests will satisfy the actual demand of the sewage in the plant and will produce a residual chlorine content in the sewage 15 minutes after dosage. In the summer the reverse is true. Therefore, a series of *Dosage Fac-*

TABLE II

FACTORS FOR DETERMINING CHLORINE DOSAGE

Seasonal Dosage Factors for the Determination of the Chlorine Dosage for Any Hour from the Analysis of a Sample of the Previous Hour

Season Hour	Jan., Feb. and Mar.	April	May and Dec.	June and Nov.	July and Oct.	Aug. and Sept.
8:00 A.M.	0.9	0.9	1.0	1.1	1.2	1.3
9:00 A.M.	1.0	1.0	1.1	1.1	1.2	1.3
10:00 A.M.	1.0	1.1	1.2	1.2	1.3	1.4
11:00 A.M.	1.0	1.1	1.0	1.2	1.3	1.4
12:00 Noon	0.9	1.0	0.9	1.1	1.2	1.3
1:00 P.M.	0.9	0.9	0.9	1.0	1.1	1.2
2:00 P.M.	0.8	0.8	0.9	1.0	1.1	1.2
3:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
4:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
5:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
6:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
7:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
8:00 P.M.	0.7	0.8	0.9	1.0	1.1	1.2
9:00 P.M.	0.6	0.7	0.8	0.9	1.0	1.1
10:00 P.M.	0.6	0.7	0.8	0.9	1.0	1.1
11:00 P.M.	0.6	0.7	0.8	0.9	1.0	1.1
12:00 Mid.	0.5	0.6	0.7	0.8	0.9	1.0
1:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
2:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
3:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
4:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
5:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
6:00 A.M.	0.5	0.6	0.7	0.8	0.9	1.0
7:00 A.M.	0.7	0.8	0.9	1.0	1.1	1.2

tors to fit operating conditions were developed for the various seasons as shown in Table II, for Buffalo.

Having determined the demand of the raw sewage in p.p.m., then by the use of the various tables the *Dosage Rate* in pounds per million gallons can be calculated for the succeeding hour. The value multiplied by the flow gives the setting for the chlorinators accordingly for the succeeding hour.

As might be expected, there are exceptions which will not fall into this regular routine. The tests on the chlorinated effluent samples are an aid in checking operation and exceptional conditions. Any continued over-or-under-chlorination calls for adjustment of the dosage factor. Likewise, the test on the effluent may indicate a dosage too low to produce effective disinfection[5].

Special Conditions Affecting Chlorine Control

To meet the special conditions which arise by virtue of any one or more of a number of factors including storms, pumping schedules, and others, special rules must be developed from practical and theoretical considerations.

These rules must consider such items as, over or under-dosages, sudden changes in rate of flow because of changing pumping schedules, desired disinfection of storm flows, abnormal chlorine demands caused by industrial wastes, false end-points, or effect of digestion tank supernatant liquor.

Maintenance of Chlorination Equipment

Mechanical difficulties with chlorinators may include some unusual occurrences, repairs, or cleaning.

For example, during the summer months, insects prevalent in the locality, may add to the difficulties of operation when the insects alight in the water of the bell jar tray and are drawn into the apparatus plugging the water lines. Uneven pressure exerted on the rim of the jar by the stops being too tight may cause strain, and sudden differences in temperature between gas and water contribute to the cracking, but greater care and attention to these details will reduce this breakage.

Accumulation of chlorine "taffy" in the evaporators may result in sudden discharge into the bell jars at times. Some of this material is high in ferric chloride and the fact that pipe lines have been found to contain ferric chloride indicates a possible reverse migration of water. This migration may occur due to back pressure in idle chlorinators.

It has been observed that chlorine solution backing up into idle machines from the discharge lines occurred apparently because of chipping of the glass ball check valves in the lines from the individual chlorinators. The corrosive solution causes disintegration of the chlorine needle valve stems, thereby requiring more replacement of this item than any other. It is, therefore, expedient to keep idle machines operating under a slight vacuum, and frequently to drain all tubes and valve chambers to insure removal of the corrosive solution. Pressure reducing diaphragms have had to be replaced because they developed fine pin holes, possibly due to corrosion induced by the suspected reverse migration of water.

Cleaning of various items may be by several methods. Carbon tetrachloride or acetone to clean bell jars of "gum"; steam followed by hot air or acetone to clean iron pipe lines carrying liquid chlorine.

In summarizing, it should be pointed out that the details of this method of dosage control are subject to revision as chemical, bacteriological, and operating data are obtained, but the fact that the disinfection results[8] have been most satisfactory indicates that the principles of the system are basically sound.

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KILLING ROOTS IN SEWERS WITH COPPER SULPHATE

By J. W. McAMIS

Superintendent Water Works and Sewerage, Greenville, Tenn.

Roots give a great deal of trouble in the smaller sewers, by causing stoppages wherever they may happen to find an entrance into the pipes carrying domestic sewage.

For four or five years now we have been using copper sulphate to combat this trouble.

We have a man whose duty it is to visit each manhole in the system at least once each month, looking for stoppages. He carries along on these trips a small bag or bucket of copper sulphate and drops a small handful of crystals down into the flowing sewage wherever he finds that the stoppage is downstream.

After a reasonable amount of experience in this work a man can tell pretty well where trouble is to be expected in the near future, by the nature of the flow of the sewage and by the conditions in the bottom of the manhole.

In cases where stoppage is due to roots, sewage will back up into the next manhole above during periods of greatest flow during the day and will recede during periods of low flows. This condition may exist for days or possibly weeks before the sewage begins to overflow the top of the manhole and run into the street. By throwing in the copper sulphate crystals *while the sewage is still flowing*, a sufficient concentration of the poison will usually reach the seat of the trouble to eliminate it before the stoppage is complete.

At Greenville, we have the same man doing this work that looks after the disposal plants and he tells me that he can predict almost exactly when the balls of roots will turn loose and come down to the treatment plant following the copper treatment.

Since we have been using this scheme it is a rare day when we have to send out a truck with sewer-rods and other equipment to open up a stopped sewer.

Regarding the exact quantity of the sulphate required for good results, I have attempted no determination of the necessary concentration of copper sulphate. However, it is my opinion that the length of the contact period is a more important factor than the actual concentration of the copper sulphate. To illustrate; the ideal condition seems to be where a small flow of sewage, say two to five g.p.m., is just trickling through a mass of roots. In a case like this a small handful of the chemical applied in the manhole just upstream from the stoppage will do the trick.

If the flow is greater, as determined from looking in the manhole just below the stoppage, greater quantities and possibly repeated applications would be necessary. If it is kept in mind that it is time of contact that is important, rather than the amount of copper sulphate, no trouble should be experienced in carrying out this operation.

Another important point to remember is that it is useless to apply the copper sulphate in a sewer that is completely stopped, for unless there is at least a small flow of sewage through the obstruction there is no chance for contact between the roots and the copper solution. Sewer rods would be the only remedy here—at least to start some flow through and allow the copper to reach the roots. (Since it is only necessary to kill the small root which enters the sewer, and not the great mass of roots branching from it, the important factor is that of reaching the feeder root with the killing chemical. Then, the flow pulling on the large heavy "brush," causes the weakened base root to break. Prechlorination of sewage has been found to produce the same results on root infected sewers but is not so simply applied as the copper treatment.—Ed.

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Boston	Columbus	Jacksonville	Monrovia, Calif.	Roanoke	Syracuse
Bridgeport	Dallas	Kansas City	Oklahoma City	Salt Lake City	Union City
Buffalo	Denver				Washington, D. C.

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DISINFECTION OF SEWAGE

The need for sewage disinfection cannot today be overlooked. With increasing population the growing demands on water supplies necessitate using sources of supply hitherto considered unsuitable. The increasing popularity of swimming has led to the use of the most available bathing beaches, lakes and water courses. The national resentment against the pollution of streams and rivers is gaining momentum. All of these have centered the attention of sanitarians on sewage treatment. As a final measure of securing complete health protection, sewage disinfection, with chlorine, is accepted practice.

W & T Master Automatic Visible Vacuum Chlorinators, Stamford, Connecticut, Sewage Treatment Plant.

ODOR CONTROL

The control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulfide (the gas responsible for these obnoxious odors), or prevention of its formation by controlled application of chlorine, is not only quite practicable but also results in economy of operation due to reduction of deterioration in interceptors and allied appurtenances.

B.O.D. REDUCTION

Treatment plants discharging effluents into water courses having extreme seasonal variation in flow have profited from controlled chlorination to reduce biochemical oxygen demand. Field tests have often shown a reduction in the five day B.O.D. of up to 30 per cent.

OTHER ADVANTAGES

Similarly, chlorine prevents filter "ponding." It is also widely used to prevent sludge "bulking." Where grease is a problem, chlorine will aid in its removal and minimize its accumulation in small pipes and spray heads. When added to return supernatant liquor from digesters, chlorine tends to counteract the impact of highly putrefactive liquids from fresh sewage. The thickening of sludge may be greatly benefited by the maintenance of a "chlorine blanket" in the supernatant above the sludge. Chlorine is also useful in the preparation of coagulants such as "chlorinated copperas." Difficult trade wastes, such as those containing cyanides, can be effectively purified by designing means for the application of chlorine into the process.

EQUIPMENT

For every sewage plant, there is W&T Equipment to fit. Visible Vacuum Chlorinators with capacities from ounces to 6000 pounds per day—Solution Feed and Direct Feed Chlorinators for small plants—and Reagent and Chemical Feeders to meet many varied chemical treating applications. All W&T Apparatus is backed by over thirty years' experience and is job-engineered by chlorination specialists.

TECHNICAL INFORMATION

W&T representatives will gladly discuss any sewage chlorination problem. Technical bulletins on the many phases of sewage chlorination and W&T Chlorinators will be sent free on request.

CONTROL OF ODOROUS AND DESTRUCTIVE GASES IN SEWERS AND TREATMENT PLANTS

By CHAS. C. HOMMON

Late Supervisor of Sewage Treatment
Canton, Ohio

THERE are heterogeneous odors from sewers and sewage treatment plants. The so-called sewer gas often referred to in nontechnical language by the layman is not a specific gas. It is an all inclusive term meaning any gas or combination of gases that may be found in a sewer. The most objectionable and far-traveling odorous gases are those originating from stale and septic sewage. Of these volatile compounds, which are expelled from septic sewages, hydrogen sulphide is by far the greatest offender.

This gas, besides creating odor nuisance of intensity and travel distance in proportion to its concentration, has a second and decided objection. It is a dangerously toxic gas in dilution higher than most operators and engineers realize. By authorities it is rated with hydrocyanic acid gas in respect to its toxicity. It is treacherous because individuals working in fatal concentrations lose their sense of smell. Operators working in less than fatal concentration become accustomed to the odor but in time suffer permanent injuries—notably conjunctivitis and respiratory tract inflammation.

Destructive Effects of Sulphide Gas

In addition to the toxicity, hydrogen sulphide is responsible for costly damages to sewers and plant equipment. Copper parts on expensive switchboards and control panels are in short order sulphided and flaked away or crumble to black copper sulphide powder. Short work is made of copper screens and brass work exposed to the moist gas at sewage plants. The first sign is the iridescent blue coloring imparted to copper and its alloys. Hydrogen sulphide can also be easily and simply detected by exposing silver coins for a few hours at points where presence of the sulphide gas may be suspected. The coins turn brown and then black if sulphide gas is present.

Then, one of the most disastrously damaging effects from hydrogen sulphide is its hidden attack. This is the acid disintegration of masonry sewers and all metal parts of manhole structures. The sulphide gas in this type of attack is converted by organisms (bacteria) on the walls of sewers into two acids, sulphurous and sulphuric. It hardly needs be explained that both of these acids make short work of concrete or mortar. The calcium sulphate produced causes rupture of mortar pipe joints and brick sewers or manholes. It has been known to weaken sewers to the point of complete failure of that part above the sewage flow line, below which no damage is done. Therefore, no full flowing sewer is ever damaged by sulphide gas. This gas is never oxidized by organisms which are present in the liquid but only those which thrive in an atmosphere where there exists some oxygen. If, therefore, it were practical to seal sewers so as to prevent all entry of air, there would be no danger of the so-called gas attack of sewers and manholes.

An Instance

The sanitary outfall sewer extending from the southerly city limits of Canton, Ohio, to the treatment plant offers good evidence as to the destructiveness of sulphide gas.

This sewer is 39 inches in diameter, 6.5 miles in length, and was placed in service in 1915. Type of construction was vitrified segment block laid up with mortar joints, and has a theoretical carrying capacity of 18 m.g.d. There is one depressed section, 3,200 feet in length, which is constructed of reinforced concrete. This length of sewer is naturally conducive to septic sewage and consequent development of hydrogen-sulphide, especially during the warmer months of the year. The presence of offensive gases was not particularly grievous with the Imhoff contact bed type of sewage plant that was the original companion unit of this outfall sewer. However, in 1925, when the original contact bed units were converted into trickling filters using the conventional spray nozzles that were in general use at the time, the volatile gases made their presence known through the atomizing effect of the spray nozzles. Thus originated a definite odor problem.

An Early Study in Corrective Treatment

In about 1928 through the efforts and assistance of Mr. L. H. Enslow, associated with The Chlorine Institute, some work was undertaken using liquid to control the odors. The Institute furnished the chlorine and the firm of Wallace and Tiernan loaned the necessary chlorine feeding apparatus for the study.

Chlorine was first added to the sewage at a point locally known as the three way manhole, which is the beginning of the main outfall sewer. This station is 6.5 miles above the Treatment Plant and is the point of convergence of three main trunk sewers.

A number of sampling points were established along the sewer for collecting samples for analysis. It was soon learned that the chlorine would do the trick of controlling the hydrogen-sulphide. However, it was difficult to maintain sufficient chlorine and the required dosage was relatively high. The receding area in the depressed section caused an appreciable increase of hydrogen sulphide which, it was believed, defeated the desired results at the plant. It was obvious that split feeding was the answer; just how many points of desired application were not determined because of the absence of necessary water pressure for operating the chlorine machines at locations below the three-way manhole.

The chlorinators were then moved to the sewage plant and chlorine admitted to the raw sewage just ahead of the bar screens.

This work clearly indicated that a dosage of 10 to 12 p.p.m. would greatly improve conditions at the plant and eventually permanent chlorination equipment was purchased and storage racks for handling ton containers of chlorine were constructed. At this time odor control was the all absorbing question, with only minor consideration given to the need for deterring disintegration of the mortar tile joints and concrete structures.

Attack on these, however, became accelerated in the time intervening and the expensive Canton outfall sewer, weakened by joint attack, has ruptured three times in the past few years. Internal pressures, caused from surcharging, proved too much for the weakened joints. These failures offered good reasons and opportunities for a thorough inspection of the sewer and it was found that practically all of the mortar joints above the normal flow line had disintegrated and ceased to exist. Also many of the liner plates were split off and were found lying on the floor of the sewer. It is assumed that the swelling of the mortar in the joints during the sulphating period created sufficient pressure to pinch off the faces of these tile. In a few instances the velocity of the sewage had caused these fallen plates to gather into sufficient piles to develop major restrictions in the sewer. It was interesting to note that the portion of the sewer below the normal flow line was in a very satisfactory condition, no plates missing and all joints normal, whereas the upper areas showed serious attacks. This same condition prevailed in the approaches to the concrete depressed section. Wherever the concrete mortar was submerged it was in a satisfactory condition, but above the normal flow line (those areas normally in contact with moisture and the gases) serious deterioration was evident.

A great deal more is known today about sewage treatment and the handling of sewage than was available when the Canton outfall sewer was constructed and the writer is frank in admitting that he did not fully appreciate what had occurred or what was occurring in the sewer at the time this investigational work was being done. As a matter of fact, there was little if any evidence in 1928 to show that the attack was proceeding at a serious pace, and chlorination at the plant proper seemed adequate for the odor problem.

Methods of Preventing Sulphide Production

Hydrogen sulphide develops only after all other sources of available oxygen utilizable by bacteria have been exhausted. After this, the oxygen hunger of several species of bacteria is satisfied from the only source left—the sulphates. In taking away the oxygen, the residue is sulphide, which hydrolizes into hydrogen sulphide.

Having laid down this premise, it becomes apparent that there are two general methods of preventing or checking sulphate breakdown. These are:

(1) Introducing more oxygen in the form of air, dilution water containing oxygen, or an oxygen containing compound such as nitrate.

(2) Suppression of bacterial activity and multiplication of organisms which deplete the oxygen and eventually break down the sulphates for their oxygen content.

The sewage operator may employ the following corrective methods:

(1) Air blowing to sweep out most of the volatile (free) hydrogen sulphide and discharge of the air-sulphide exhaust through a tall stack. Or absorption of the sulphide in the exhaust may be attained by passing it through an absorption tower.

(2) Destruction of the sulphide in the sewage by addition of chlorine, which precipitates the sulphur *in situ* and deodorizes in so doing.

(3) The fixation of the sulphide by adding a metallic salt such as copper or iron.

These several methods will now be discussed separately.

(1) Oxygen Introduction

Air blowing in the sewer sounds attractive but has many drawbacks of a practical nature. The scheme has never been successfully developed because of structural and operating expense. The effect secured with flash aeration has short duration, as all activated-sludge plant operators will attest. As a matter of fact, a small air input is worse than none in the overall result, since bacterial multiplication is given impetus and oxygen supply is too limited.

The addition of nitrates (Chilean Saltpeter) has been used; is effective but surprisingly costly in terms of oxygen units provided.

Dilution, by introducing reasonably clean stream water up-sewer, has been utilized with excellent results during hot dry-weather flow when the practice is most needed, and fortunately is permissible at such times without surcharging sewers or imposing excessive flows on treatment works. Fortunate is the plant manager who can divert a portion of a stream into his sewer system when most needed to maintain clean sewers, dilute and freshen sewage delivered to the plant at much younger age, and prevent degradation and odor production in the system.

(2) Suppression of Bacterial Activity

In winter, lower temperatures of sewage is the natural suppressor of bio-activity. If it were practical to chill sewage to maintain temperatures of not in excess of 70° F. during its travel through the system there would be no odor or sewer attack problem.

The practical alternative is that of partial disinfection of sewage to reduce the total numbers of organisms, suppress their development, and most important of all, to reduce the biological "turnover." What is meant by "turnover" is the number of new generations of young and vigorous organisms per hour. Like all living things, it is the active youth generation who burn up the oxygen in the vigor of living, and not the grandfather generation. Total numbers of organisms may mean little if anything in sewage. What really counts is the age, activity and species of bacteria. This means much in rate of oxygen utilization and depletion, consequently, the speed of reaching the point of sulphide production and its consequences.

To suppress bacterial "turnover" and rates of oxygen depletion, such as is provided by nature in winter operation, is the basis on which partial disinfection of sewage as close to the point of origin as practical, has met with success. Some remarkable results have thus been obtained with up-sewer chlorination at rates of dosage dictated by the temperature-time factor. In some instances (cooler sewage and short period of travel to the plant) as little as 2 p.p.m. of chlorine has been ample. In other instances (drought and high temperatures with long travel periods to the plant) as much as 12 p.p.m. has been required. In others, a two-point application, between the collecting system and the plant, has been required for higher efficiency and chlorine economy. Taking it by and large, the 5 p.p.m. dosage has been effective when applied sufficiently early—i.e., before bacterial "turnover" has gotten a head-start.

During the past several years "preventive chlorination" has been the most popular odor control measure. No set rule can be given for the dosage needed, for reasons above cited. Nor can a universal specification be written concerning the point (or points) of chlorine introduction up-sewer. Therefore, in cases where doubt exists, a hydrogen sulphide and chlorine-demand survey to determine the most effective application point (or points) is the recommended procedure. As a matter of fact, a portable chlorinator may be employed to determine the permanent location (or locations) for maximum chlorine economy.

In connection with such surveys and chlorination point selection, securing assistance of experienced engineers with The Chlorine Institute, 50 E. 41st St., New York City, or the technical service staff of Wallace & Tiernan Co., and/or of the larger chlorine producers, is suggested.

Other Corrective Methods

In cases where it has not proved practicable to adopt preventive measures, the following corrective methods are available.

(1) Air Blowing at Plant

So far as we are aware, this method has only been utilized at one plant—Dallas, Texas. In a closed chamber the sewage arriving at the treatment works is air-blown for 4 minutes and in the second pass is blown for an additional 4 minutes with air carrying chlorine gas. The exhaust from the aerating and aerochlorination chamber is discharged through a stack. The plant is also equipped to employ ordinary chlorination or the addition of an iron salt, which will destroy or "fix" the volatile sulphides, as later explained.

(2) Chlorination

By far the greatest number of plants have been equipped for corrective chlorination at the plant proper, when and if odors become a problem. Particularly has this method been mostly adopted for the smaller plants and those where odor nuisance is a possibility rather than a probability.

In this method, chlorine is applied just ahead of the bar-screens or in the pump well. The dosage varies considerably, running from 2 to 20 p.p.m. of chlorine. In the majority of such cases, the 10 p.p.m. dosage covers the requirement. The practice of pre-chlorination for the dual purpose of disinfection and odor control simultaneously has gained considerable favor in recent times, the largest plants to adopt this method being those of Buffalo, N. Y., and Detroit, Mich., where pre-chlorination has also proved more economical than post-chlorination, and also more effective as a disinfection measure alone.

In the plant chlorination method the sulphide is destroyed by breaking into the compound and precipitating the sulphur thus

$$H_2S + Cl_2 = 2HCl + S$$

(3) Sulphide Fixation

When adding chlorine *solely* for the purpose of sulphide destruction (i.e., after the sulphide has been produced), the scheme is less effective than the following.

Copper or iron salts may be employed for the purpose of converting volatile sulphide into "fixed" copper or iron sulphide. Since copper is the more costly metal, and since iron chloride can be produced relatively simply and inexpensively on the site of application, this scheme has in recent times become a very popular, effective and inexpensive method.

The iron chloride is produced from scrap iron and chlorine by passing the discharge of a chlorinator upwards through a tank or tower containing the iron scrap. The overflow from the tower is ferrous chloride ($FeCl_2$). The process introduced in Oklahoma City by L. H. Scott, Supt. of Water and Sewage Treatment, and H. J. Darcey, Chief Engr., Oklahoma State Dept. of Health, and known as the Scott-Darcey Process, was taken over and perfected by Wallace & Tiernan Co. In the West and Southwest the method has been rather extensively and effectively used. With the equipment, either iron chlorine or chlorine may be used at will. The equipment can also be operated to produce ferric chloride ($FeCl_3$) for coagulation or sludge filtration at will.

In the matter of odor correction, the use of chlorinated iron has many advantages over direct chlorination. For instance, there are stale sewages which when chlorinated partially develop decidedly medicated (iodoformish) odors. This odor is not of a traveling nature but is not pleasant and visitors would object to it. On the other hand, chlorinated iron produces absolutely no odor. For a given amount of chlorine, use of the Scott-Darcey method insures 100 per cent efficiency in respect to theoretical hydrogen sulphide removal per pound of chlorine. The explanation lies in the fact that the iron has affinity only for the sulphide and fixes it completely without organic matter interference, while chlorine is always in part used up by organic matter before it strikes the sulphide. Frequently 50% of the chlorine applied is thus used up and only 50% ever reaches the sulphide.

A fact of considerable interest also is that the iron application can be made at any point desired. If, for instance, it is desirable to add it at the beginning of a long sewer, the iron is used up only as hydrogen sulphide is produced. Therefore, the surplus of iron travels along in contact with the sewage or industrial waste without being depreciated in any degree by the organic content. Thus, the iron becomes available as needed during progress of the sewage between the point of application and the plant. It is plain, therefore, that the chlorinated iron method is a measure of correction which involves the utilization of chlorine to its highest advantage. The method insures an efficiency of hydrogen sulphide removal at essentially 100 per cent of the theoretical, this being the destruction of 1 p.p.m. of H_2S for each 2 p.p.m. of chlorine applied, according to the reaction:

$$H_2S + Cl_2 = 2HCl + S$$

The reactions involved in the chlorinated iron method are:

(1) $Fe + Cl_2 = FeCl_2$
(2) $H_2S + FeCl_2 = 2HCl + FeS$

Since two parts of chlorine by weight accounts for one sulphur, the iron involved can be pictured as a chlorine carrier in the process of "indirect chlorination."

From the above, it is readily observed that the more modern use of chlorine as an agent of controlling hydrogen sulphide would have been of material benefit in preventing failure of Canton's 26 year old outfall sewer, as well as correcting the odor problem at the plant proper. When considering the cost of a large outfall of material length it is apparent that considerable can be spent for Summer time chlorination as a measure for extending the life of such a structure.

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CHLORINE CONTAINER HANDLING TRUCK

Adaptation of Light Utility Truck, Specially Rigged for Distributing One Ton Chlorine Containers to Up-Sewer Chlorinating Stations

by FRANK H. MILLER

Chief Engineer, Hampton Roads San. District, Norfolk, Va.

THE truck here pictured is a low bed, six wheel stake truck regularly used for system service work. It has been equipped for the handling of ton containers of chlorine transported from treatment plant container stock to up-sewer chlorinating stations. Advance arrangements for utilization of the equipment required no change at the Hampton Roads Sanitation District Commission's Boat Harbor Sewage Treatment Plant, where a stock pile of some 20 containers can be maintained and swing hoist equipment was available. At the three up-sewer pumping stations, where chlorine is applied, the truck can be backed into position for easy unloading. A fence has been constructed around the cylinder storage area for safety.

Adaptation of the truck for such chlorine container handling consisted of the following:

(1) A drum type winch was bolted to a steel bearing plate and mounted at the front end of truck bed. Winch handle was lengthened and a side steady-bearing provided at the right edge of truck bed.

(2) Runners of 2" x 6" boards were provided on each side of the bed to give even spread bearing for the container, and built up stops were bolted in place in position giving best weight distribution on truck. Pin stops are provided behind the container to hold it in place—(see close-up view).

(3) Skids were constructed of 6" x 8" heart pine 12' long, the truck ends of which were supported and attached to truck bed by heavy (½" x 2½") strap iron hangers. These straps were carried about 2' along the bottom of the skids and bolted in place, bent up along the truck end of the runners and over to form hangers, which can be hooked into the bed tail channel. This channel was reinforced with ⅛" plates to assure adequate support.

(4) Dead men ties were bolted into bed tail channel for fastening two sides of spread sling.

(5) Wire rope (½") was constructed with spread V yoke to attach to truck bed with V being terminated in a single strand at about 8' from truck bed tail channel. This V sling assures stability at upper position of cylinder on skids and until cylinder is far enough down skids to assure steady bearing on both skids.

(6) For transportation of skids a rack was built up just behind the cab so that skid hangers could be inverted, hooked in place and suspended over cylinder during haul.

In operation the chlorine container is placed at bottom end of skids, with one or both ends on small block so that the loading sling can be pulled under the cylinder. Sling yoke is then attached to dead men. Then by turning winch cylinder is rolled up the skids and on to truck bed. On this flat surface it is readily rolled into position on bed by hand. Although two men usually work together, it is possible for one man alone to carry out the entire operation with no heavy lift or pull required.

Unloading is merely a reverse of this procedure, with the placing of cylinders largely controlled by positioning of truck.

Most of the equipment used was salvaged from odds and ends on hand. Fabrication was effected in the Commission's shop, with only about one man-day being required for the work. The original idea for this equipment was that of John D. Coenen.

Light Utility Low-Bed Truck Equipped to Handle Ton Chlorine Containers
Safety loaded container on truck and close-up of loading winch and container in position.

Truck Loading or Unloading Sequence
A one man operation, with winch and loading cable of ½ in. wire rope.

LOCATING LOST SEWERS AND MANHOLES*

By E. T. CRANCH
Director, Department of Public Works, New Rochelle, N. Y.

IF YOU have sewers, drains and manholes for which you have no records or for which available records are inaccurate, then, perhaps, some of the experiences recounted here may be of practical interest.

The settlement of New Rochelle, New York, was started in 1688, and it has enjoyed a consistent and rapid growth since then. It was incorporated as a village in 1858 and became a city in 1899. The 1940 federal census gives the population as 58,408. The area of the city is 10½ square miles.

I have had occasion to investigate a situation where there were constantly recurring floods. I found a 24-inch vitrified tile drain completely plugged. From a point where an open brook entered this pipe, it was approximately 1,000 feet to the first manhole. The city had no plan of this drain. I contacted the developer and found he had no plan, but I took him to the location and he showed me, as well as he could remember, the course of the drain, which, it seemed, followed a reverse curve. The drain was laid with open joints, and went through a swampy area in which there were a number of willow trees.

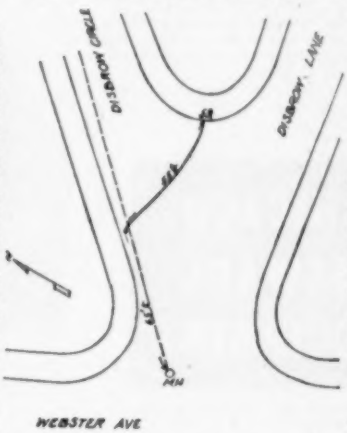
This led me to believe that the stoppage was in all probability caused by the entrance of willow roots into the drain. This spot was too far away to be reached satisfactorily with flexible sewer rods from either opening in the drain. We therefore decided to put in a manhole in the swamp area. After four days of digging we finally located the drain at a depth of about 5 feet and opened it. We found the pipe completely filled with roots and it took almost two weeks of work to clear the line. This experience made me feel that there ought to be some means of locating underground sewers and drains.

I was familiar with the use of the M-Scope in locating underground water mains. So I asked the salesman to try it out on this drain with flexible sewer rods inserted in the drain. We got 238 feet of rods in the drain, placed the transmitter on the rod and also, by means of the wire and clip provided, connected it to the rod. With the receiving set we were able easily to follow the course of the curving drain for about 200 feet. At this distance the signal became rather faint, but one man with keen ears followed it for the full distance of 238 feet.

We then rigged up the transmitter and receiver on the carrying sticks and went over the line to see if by any chance we might find any hidden manholes. At one point, right over the line, we got a sharp signal and started to dig feverishly for the manhole, only to find that a steel barrel hoop was buried in the ground. However, this demonstration satisfied me that the instrument could be used satisfactorily, for the purpose of locating both tile drains or sewers and buried manhole covers.

At another time, to relieve a flood condition, we wanted to install a new catch basin in the middle of a block and connect it to an existing drain at a manhole shown on the map at about the point we wanted. There was, however, no evidence of the manhole on the ground. With the M-Scope we located the manhole within a few minutes, just off the paved area, and under about 3 inches of sod. This time it was really the manhole.

Another time the map showed a drain manhole on the east side of the street at a certain intersection. The M-Scope gave no signal on the east side of the street but gave a clear signal on the west side of the street and, sure enough, we found the manhole about 8 inches deep under the macadam pavement.



Location of point of intersection of catch basin lateral and main drain simplified by use of M-Scope at New Rochelle, N. Y.

We had a sewer and a drain running through a private right-of-way. The map showed a manhole on each. The sewer and drain had been installed 14 years ago. For the past several years periodic efforts had been made to locate the manholes, but without success. This right-of-way had several angles in it. It passed through a fine estate and the property was so thickly landscaped with evergreens, paths, gardens, etc., it would have been almost impossible to have resurveyed the right-of-way without doing real damage to the property. With the M-Scope we located and uncovered both manholes within an hour. One manhole was covered with about a foot of dirt and the other with about 3 inches.

Another time we tried to follow the course of a drain, about 15 feet deep, which ran through territory covered with thick brush, so that it was impossible to follow the line directly from the manhole. The first open land was almost 200 feet away from the manhole and transmitter, but no signal whatever could be picked up there. We cut an opening in the brush about half way back, and were able to pick up the signal at that point. For deep drains it is necessary to limit the distance from the transmitter.

Another failure we had was in trying to find a couple of catch basins that we thought were located near an abandoned railroad bridge, where the land is thick with brush. Following along the gutter we picked up a signal on each side of the road and thought we had located the catch basins, but digging down we found nothing. I then found I could follow the signal across the road. There is a 24-inch drain at this point, installed by the old railroad company, and apparently 24-inch cast iron pipe was used to cross the road. This experience illustrated the fact that in locating catch basins or manholes, when a signal is picked up, it must be tested from every direction to see that it is not emanating from a pipe line.

In a road improvement job we had a 15-inch storm drain in the road and a catch basin on one side of the road with a lateral connecting to the drain at an unknown point. We wanted to install a new catch basin on the opposite side of the road, connect this basin to the drain at the same point as the lateral from the old catch basin and build a manhole at the junction of the three lines. The accompanying sketch illustrates the condition we faced. We ran the flexible rods through the lateral from the old catch basin and, much to our surprise, found that it followed a curved line. As a check for the point of intersection, we

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We have also used the M-Scope to trace the meandering drain laid in 1894 and mentioned at the beginning of this paper. Here the instrument proved very effective and also located two manholes which had long been covered along its course.

In conclusion, I will say that I have found the M-Scope very effective for locating the position of shallow drains for distances of about 200 feet, and for deep drains about half that distance. It is excellent for locating manholes as long as care is used in its operation, and it is understood that it will pick up any metallic substance underground, be it manhole, barrel hoop or pipe line.

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Braintree, Massachusetts, has a Flush-Kleen Sewage Lift Station, the only truly clog-proof pump for handling raw sewage or any liquid containing coarse stringy matter. This is one of over 5000 Flush-Kleen Lift Stations in daily trouble-free operation throughout the world. Samuel M. Ellsworth, Engineer.

DIGESTION OF GARBAGE WITH SEWAGE SOLIDS*

By DAVID P. BACKMEYER

Formerly, Supt. of Sewage Treatment, Marion, Ind.
Presently, Supt. Little Miami Sewage Treatment Plant, Cincinnati, Ohio

THE data and discussion material in this paper are divided into two sections or parts. The first consists of a brief description of the garbage grinding and disposal facilities at the Marion sewage treatment plant, together with some operation figures which are intended to illustrate what dual disposal has done both to and for the treatment plant during the past five years. The second part is a brief review of a series of experiments that were conducted with small digestion units of 25 gallons each. This latter work is not yet completed, and more information will be available from it later.

Dual Disposal Experience

About five years ago the first motorized collection equipment was purchased and put into use by the city garbage department. As the then recently completed sewage treatment plant was equipped for grinding and disposing of garbage, city officials at that time were anxious that this equipment be given a fair trial, in an effort to find a sanitary method for final disposal of the garbage. In the month of May, 1941, 18 tons of green garbage were brought to the plant for grinding as a first test of the facilities provided in the original plant.

Handling of Garbage

The garbage disposal installation was more thoroughly tested during the next few months. In September of the same year 162 tons of green garbage were ground and added to the raw sewage at the wet well. The method of handling the garbage at the plant was extremely simple. The garbage was dumped from the trucks onto the grade floor and then shoveled into the grinder hopper. Tin cans, trash, crockery, pieces of metal, etc., were sorted out as the garbage was shoveled.

*From *Sew. Wks. Jour.*, Jan., 1947. Reprinted by permission of the Fed. Sew. Wks. Assns.

The ground garbage was discharged from the Jeffrey garbage grinder to the raw sewage wet well beyond the sewage screens. The raw sewage pumps then discharged the garbage solids with the sewage solids to the grit channel for the removal of sewage grit and garbage mineral matter. Preaeration tanks at the head end of the primary tanks afforded a means of releasing the grease for removal by skimming at the effluent ends. The main bulk of the garbage solids was removed as sludge with the sewage solids, and pumped to the digesters for digestion.

Three definite problems soon arose from this method of handling the garbage solids. First, an excessive amount of time was required for drawing sludge from the primary tank sludge hoppers. When seven or eight tons of garbage were handled in one day, one operator would spend most of the day getting the sewage-garbage sludge mixture into the digesters. Secondly, the load on the secondary treatment, which is by activated sludge, was found to be considerable as a result of the release of colloids and solubles from the finely ground garbage. In the third place, a large amount of floating material would get past the grease skimmers and make an unsightly mess when it would collect on the wiers of the final settling tanks. The answer to these problems seemed to lie in the development of a system in which the garbage could be gotten into the digesters without first mixing it with the sewage.

In May of 1943 the flooded condition of the Mississinewa River permitted by-pass of the flow to the treatment plant for a few days, and during this period a portion of the raw sewage wet well was partitioned off for use as a separate garbage well. The necessary piping was installed for removal of the garbage, and for cleaning out the residue from the bottom of the well. The general plan of the well as it is being used today is shown in Fig. 1.

Several changes in the method of mixing the ground garbage have been made in the past two years. The agitation in the well must be sufficient to prevent the garbage solids from "caking" at the surface of the accumulation, this trouble being more pronounced during the corn canning season. If the ground garbage is left in the well for a period of 10 to 24 hours, lime must be added to control the pH. Two bags of hydrated lime (100 lb.) are usually sufficient to hold the pH above 6.0 when the 3,600-gal. batch is not pumped to the digesters for a period of 18 to 24 hours.

TABLE I.

Data on Garbage-Sludge Digestion at Marion, Ind.

Month	Volatile Solids Loading		Bottom Sludge in No. 1 Digester		Volatile Solids Removed as Gas (lb.)	Volatile Solids Reduction (%)	Raw Sludge Total Solids (%)	Ground Garbage Total Solids (%)	Digested Sludge	
	Pounds	Lb. per Cu. Ft. per Day[1]	Solids (%)	Volatile (%)					Total Solids (%)	Vol. Solids (%)
1945										
April	154,500	0.062	4.55	45.0	109,000	70.5	5.29	6.00	4.19	38.9
May	143,200	0.055	4.36	44.6	116,300	81.4	4.99	5.13	4.55	39.7
June	202,000	0.081	4.00	44.3	136,500	67.5	5.93	4.23	4.22	39.8
July	210,200	0.081	3.94	45.2	150,800	71.7	5.40	4.24	4.07	39.2
August	224,200	0.086	3.37	48.8	145,500	65.0	4.55	4.11	3.74	43.0
September	223,900	0.089	2.98	52.8	160,500	71.7	4.39	5.23	3.18	46.6
October	172,800	0.067	2.84	54.6	118,100	68.4	4.09	4.52	3.10	52.1
November	171,300	0.068	3.34	57.5	125,300	73.2	4.66	5.00	3.47	52.9
December	140,200	0.054	3.40	58.7	112,000	80.0	3.86	4.55	3.41	53.2
1946										
January	144,400	0.076	4.90	65.6	110,900	79.0	4.71	5.84	3.17	53.9
February	178,600	0.076	5.05	67.1	110,900	62.0	4.72	6.88	3.71	54.0
March[2]	189,900	0.073	5.16	60.8	132,700	69.8	5.37	7.85	3.55	52.0
April	169,200	0.067	3.44	56.8	130,000	76.7	4.16	9.12	3.54	43.9

[1] Based on primary digester capacity.
[2] Recirculation of bottom sludge started on March 20.

TABLE II.

Results of Garbage Digestion Experiments at Marion, Ind.

Test Number	1	2	3	4	5	6	7	8
Date started	3/10/45	3/10/45	8/30/44	8/30/44	1/16/46	4/23/46	4/23/46	4/23/46
Material digested	Garbage	Garbage	Garbage	Sludge	Garbage	Garbage	Garbage	Garbage
Dry solids (lb.)	1.02	1.02	2.74	2.66	5.17	0.55	0.55	0.55
Volatile solids (lb.)	0.92	0.92	2.45	1.25	4.74	0.48	0.48	0.48
Seed material	Digester supern.	Digester supern.	Water supern.	Water supern.	Digester supern.	From Test 5	90-day supern.	90-day supern.
Temperature (°F.)	79	79	90	89	116	84	80	80
Total gas (cu. ft.)	11.48	13.05	18.93	9.02	38.6	8.8	7.53	7.27
Gas per lb. vol. (cu. ft.)	12.43	14.1	7.73	7.2	8.15	18.3	15.7	15.1
Per cent of vol. removed as gas[1]	80.7	99.1	50.3	46.7	52.8	100+	100+	98.6
Gas pressure (in. water)	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
Per cent of total gas yield in 5 days	73.0	76.3	50.0	78.6	—	38.1	25.2	24.5

[1] 100 cu. ft. gas considered to represent 6.5 lb. volatile solids.

Gas Production and Utilization

If the process of disposal of garbage by digestion with sewage solids is to be an economical one, some practical use must be made of the gas produced.

A study of the data on hand at Marion would indicate that an average yield of 260 lb. of volatile solids from a ton of green garbage should produce 2,600 cu. ft. of gas having a carbon dioxide content of less than 35 per cent by volume.

During the year 1945 the Marion digesters produced 23.6 million cubic feet of

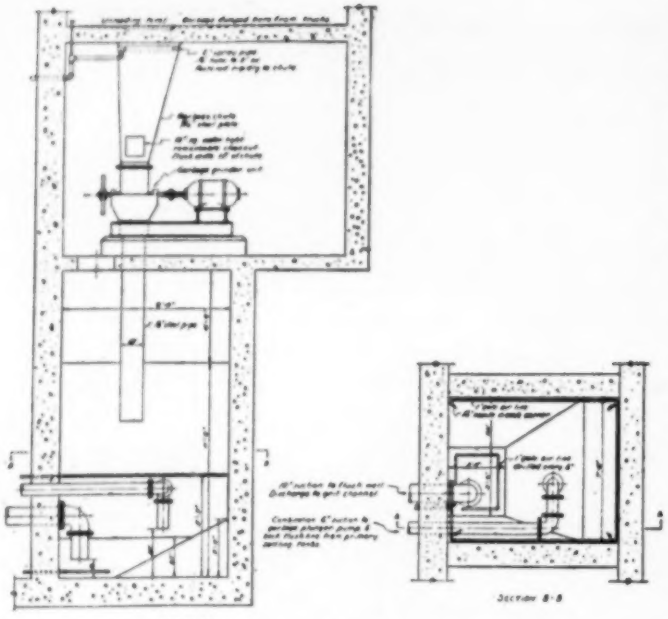


Fig. 1.—Garbage Receiving and Mixing Well at Marion, Ind., Sewage Treatment Plant.

gas, and utilized 21.5 million cubic feet at the gas engines and heating boiler. In addition to the sewage gas used, 640,000 cubic feet of gas was purchased from the utility company to fill in at certain periods when gas production was not sufficient for the total plant load.

Several interesting studies have been made in an effort to determine what percentage of the total gas generated comes from the sewage solids and what part from the garbage solids. Two methods are available for approach to this problem in actual plant operation. If the sewage load is stable, that is, not too far from average with respect to B.O.D. strength as a result of rain water dilution or industrial wastes, the garbage could be taken away for a few days and the resultant drop in gas production noted. By working in reverse order, if the garbage load were stable and the sewage load was reduced by prolonged rains, some indication would be had as to the amount of gas generated from the garbage alone.

The winter months afford an opportunity to study gas production volumes when the amount of garbage handled is very limited. Fig. 2 demonstrates the fluctuation in gas production throughout the calendar year. The curves represent the average of four years' operation by single months. It will be noted that during the first quarter of the year, when the garbage tonnage is below two tons per day, the amount of gas produced is less than 49,000 cu. ft. per day. In the months of July, August and September, the gas yield increases about 30 per cent while the amount of garbage ground increases 400 per cent. It is the writer's belief that more gas would be collected in the summer months if more digestion capacity were provided.

Fig. 3, which is reprinted from the fourth annual report of operations, shows the relationship of the various factors affecting the production of gas during the year 1944. Here the rainfall curve and the canning plant load curve are included, as both of these factors have a definite bearing on the sewage organic load.

Fig. 4 is intended to show the sag in gas yield when rain water washes out the gas-producing sewage solids, and the garbage solids must produce most of the gas. The B.O.D. curve indicates the drop in organic matter in the sewage, with the resultant drop in gas volume from 49,000 to 26,000 cu. ft. per day. Had this "washout" occurred in July, the actual drop would have been about the same, but the range would have been from 75,000 to 52,000 cu. ft. per day. The greatest volume of gas produced in any one single day was recorded in September, 1945, when 97,108 cu. ft. were metered.

In August, 1946, it was possible to study an 11-day period during which time no garbage was taken at the plant. The average daily gas production in this period was 23 per cent below the average for the 15 days preceding the period. The drop was from 68,000 to 52,000 cu. ft. per day.

Digestion Capacity

The matter of digestion capacity, where garbage is to be handled in a sewage treatment plant, is a question of common concern at this time. The term "cubic feet of digester capacity per capita" may be unreliable and misleading for several reasons. Assuming that digestion is carried on at optimum temperature and loading conditions, the variables of organic loading from industrial wastes and the seasonal changes in the garbage itself would necessarily limit such figures to a specific city or town.

The expression "pounds of volatile solids per cubic foot of primary digestion capacity applied per day" would seem to be a much more reliable way to state capacity ratings. Some of the peculiar characteristics of ground garbage may even make this method of comparing capacities questionable.

In referring to the digester loading at the Rahway Valley treatment plant, with sewage sludge only, Fontenelli and Rudolfs* reach the conclusion: "The optimum loading capacity for each 1,000 cu. ft. of primary digestion capacity would be 100 lb. of dry volatile matter per day, producing 50 per cent clear supernatant liquor." At no time during the past two years has the volatile solids loading at the Marion plant reached the 0.10 lb. per cu. ft. per day loading stated above, yet the apparent overloading of the digestion system has pro-

*Sew. Wks. Jour., 17, 4, 692 (July, 1945).

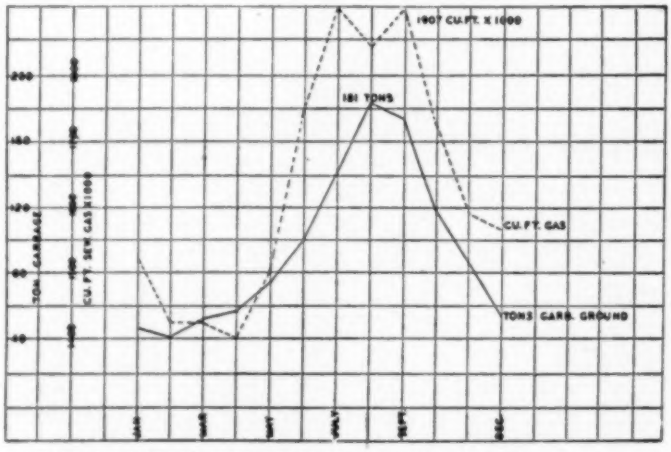
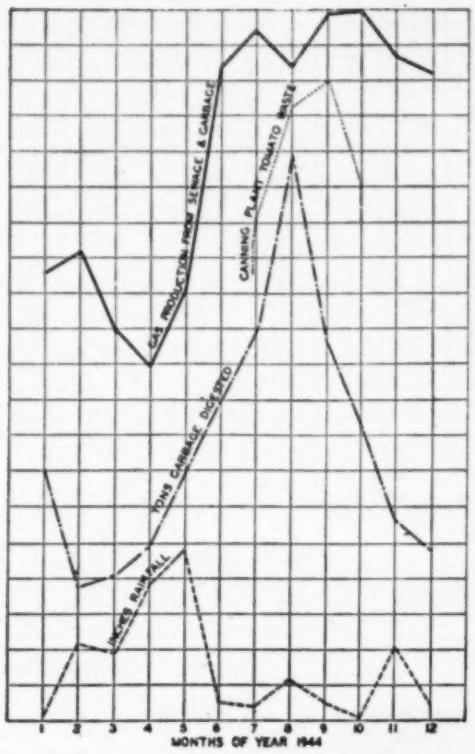


Fig. 2.—Four-Year Record of Gas Production.



Fig, 3.—Relation Between Garbage Load and Gas Production.

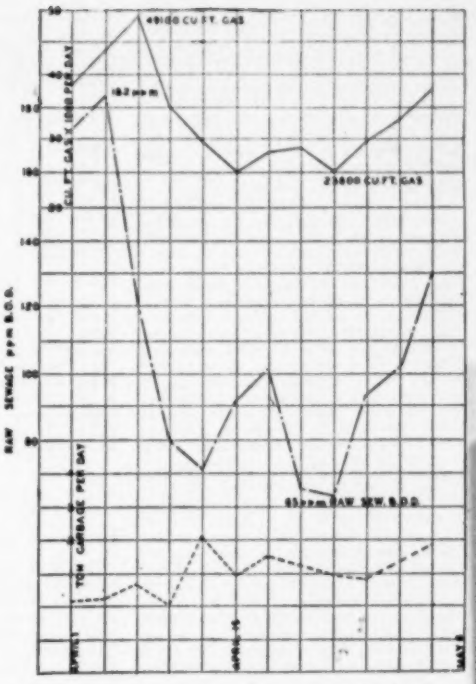


Fig. 4.—Effect of Sewage "Washout" on Gas Production.

duced a supernatant liquor in the secondary digestion tank that will contain 2.5 per cent total solids for several successive weeks at a time. This situation can be accounted for in part by the fact that some of the ground garbage particles are transferred from the primary digester to the secondary digester each day, and as a result the secondary digester is continuously active in producing gas.

It would seem logical that not only the loading of volatile matter, but also the number of cubic feet of gas produced per day per cubic foot of capacity at hand would materially affect the ability of the digester to produce satisfactory supernatant liquor. Fig. 5 illustrates the rather unusual condition which developed in the primary digester during the latter part of 1945.

It will be noted that undigested garbage solids had accumulated in the bottom of the digester, and that very little immediate digestion of these solids was taking place, as is evidenced by the volatile percentage curve which climbed to a peak of 67.1 per cent in March, 1946. The temperature of the sludge at the bottom was surprisingly low at 56° F., while the active sludge above it was 90° F.

The temperature problem was easily solved by circulating the cold, thick sludge from the bottom to a higher elevation, where it could mix with the warmer and more active solids. This circulation resulted in an immediate increase in the amount of gas being produced. The primary digester is now circulated for two hours daily as a routine operation, and the temperature of the sludge at the bottom is above 75° F.

The Marion treatment plant has a designed digestion capacity of 6.25 cu. ft. per capita for the actual 1940 resident population, but on the basis of the 1945 equivalent population, as measured by B.O.D. tests, the present capacity is 4.2 cu. ft. per capita. During the year 1945 only 20 per cent of the sludge and garbage volume put into the system was removed as supernatant liquor.

Throughout the entire month of February, 1946, there was no supernatant in either of the digestion tanks that could be withdrawn. The data in Table I show that although an average of 72 per cent of the volatile solids were removed as gas, the total solids content of the finished sludge

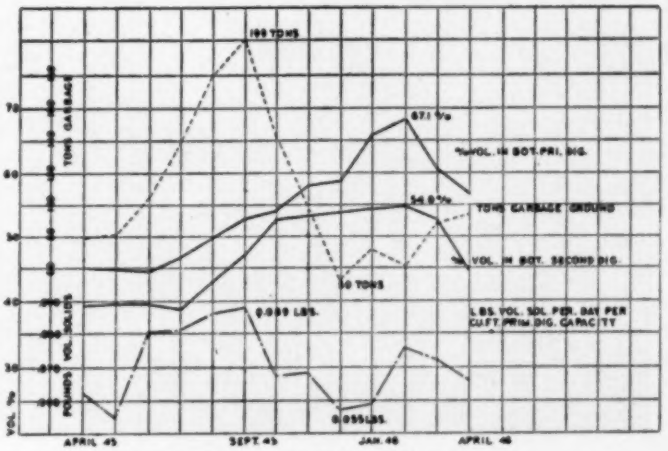


Fig. 5.—Volatile Content of Bottom Sludge in Digesters.

became increasingly lower, and the volatile content progressively increased.

It has been our experience that when the daily gas production is above 0.36 cu. ft. per cubic foot of total digestion capacity, there will be no supernatant liquor in the system that contains less than 5,000 ppm. total solids. At the same time, it does not follow that lower gas yields will always produce supernatant liquor suitable for return to the primary settling tanks.

Some indication of the time required to concentrate the sludge from the secondary digester is given by the results of tests made on the supernatant liquor. By withdrawing the liquor containing 3.0 per cent total solids and allowing it to stand without agitation in 40-gal. drums, it was found that the solids would concentrate to 4.47 per cent in 10 days, to 4.98 per cent in 13 days, and to 5.04 per cent in 24 days. These results would indicate that the sludge in the secondary tank now having a uniform solids content from top to bottom of about 3 per cent would give up about one-third of its volume as supernatant when the concentration of solids reached 5.0 per cent in 13 to 15 days.

The present volume loadings will average about 26,000 gal. of sludge and garbage per day the year through. To get an additional 15 days' digestion time, the present total digestion capacity of 167,000 cu. ft. should be increased 31 per cent to give a total capacity of 219,000 cu. ft. This latter figure would give the plant 8.21 cu. ft. per capita on the basis of the 1940 population, and 5.22 cu. ft. per capita on the basis of the 1945 equivalent population. These populations were 26,700 and 42,000 respectively

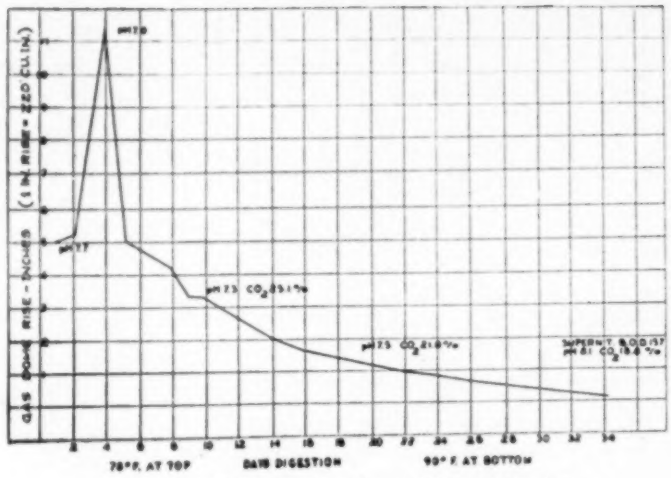

GAS FOUND RISE - INCHES (1 IN. RISE = 22.0 CU.IN.)
pH 7.0
pH 7.7
pH 7.3 CO_2 0.5 %
pH 7.3 CO_2 2.0 %
SUPERNAT. 8.00 (57 pH 8.1 CO_2 15.6 %
78° F. AT TOP
DAYS DIGESTION
90° F. AT BOTTOM

Fig. 7.—Garbage Digestion Experiment of 34 Days' Duration.

Separation of Grit and Debris

One of the troublesome features involved in adding ground garbage directly to the digesters in preference to mixing it with the raw sewage has been the removal of grit and mineral matter from the garbage. The separate well system shown in Fig. 1 has been used for the past three years at Marion, and no stoppages in pipe lines have been encountered during this period.

The removal of egg shells, bone chips, crushed peach pits, seeds, bottle caps, and various other non-digestible materials by flushing them out the bottom of a properly constructed well would appear to work out in a satisfactory manner. This statement is substantiated by the record of grit removal, which shows that during the eight months of June, July, August and September of 1944 and 1945, the average volume of grit removed per month was 65 per cent above the average removal per month for the full two years. In this same 8-month period the amount of garbage handled per month was 50 per cent above the average tonnage per month for the full two years. Some traces of egg shells, coffee grounds, chicken feathers and other fibrous materials are found in the digested sludge, but not in quantities sufficient to cause caking at the top of the digester or plugging of the sludge draw-off lines.

Fig. 6.—Pilot Digesters Used for Garbage Digestion Experiments.

Summary of Operation Experience

If the garbage disposal installation at Marion has any single quality worthy of special mention, that quality would be simplicity. No special skill or training is required of the men in charge of any part of the installation. The mechanical equipment is confined to two units, the Jeffrey garbage grinder and the Chicago single-piston plunger pump. Both units have performed the functions for which they were installed in an excellent manner.

The following conclusions are based on the five years of experience in digesting sewage sludge-garbage mixtures at the Marion plant:

1. In a properly constructed garbage well, sufficient grit and foreign non-digestible matter may be removed from ground garbage so that the remainder of the garbage solids can be digested with sewage solids without difficulty in a properly controlled digestion system.

2. The gas produced from the digestion of garbage solids with sewage solids is of a quality that will permit its use in gas engines and gas-fired heating boilers.

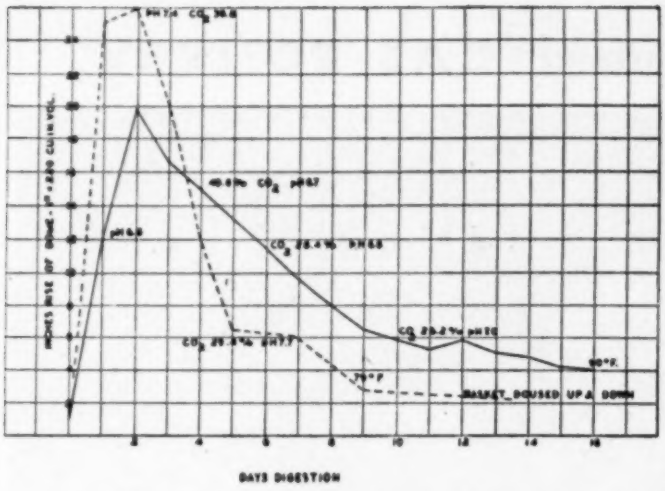


Fig. 8.—Comparison of Results of Two Experiments in Garbage Digestion.

3. The loadings (garbage solids plus sewage solids) of 0.1 lb. of volatile solids per cubic foot of primary digestion capacity per day are too great to allow withdrawal of clear supernatant liquor from the digestion system, with two-stage digestion at temperatures at 90° F.

Digestion Experiments

A previous report of pilot plant experiments on digestion of garbage solids was made in the June, 1946 issue of *Sewage Gas*, published by the Indiana State Board of Health. Some of the previously published data will be included in the summary that follows.

Test Procedure

The equipment used in the experimental work consists of three digestion units as shown in Fig. 6. Each unit was made up of a 25-gal. used paint drum, a sheet metal gas collection dome of about 16 in. diameter and a side wall skirt of 19 in., and a heating unit at the bottom for maintaining temperature control.

The general procedure was to digest raw sewage sludge or ground garbage solids in two of the three drums, and reserve the third unit as a control for the digestion medium. Throughout the course of the tests many variations of this procedure were used.

The top of each collection dome was fitted with a ¼ in. outlet so that the gas collected could be released and analyzed conveniently. The volume of gas collected was measured by the "inches rise" of the collection domes; the weight of the domes provided a working pressure of 1.75 in. water column on the gas collected.

The results of eight of the tests made are summarized in Table II. Three graphs are shown which demonstrate the gas production rates as measured by the rise of the gas collection dome each day. In Fig. 7 it will be noted that the test was continued for a period of 34 days, but that about 40 per cent of the total gas production took place in the first five days. A supernatant liquor of good quality was obtained at the end of the 34-day period as is shown by the B.O.D. content of 157 ppm.

Fig. 8 shows the results of two tests made over a period of 16 days. In the test represented by the broken line curve, 76.3 per cent of the total gas generated was produced in the first five days of the period. The solid line curve demonstrates the relation of the CO_2 content of the gas to the pH as the digestion rate changes over the 16-day period.

In Fig. 9 the broken line curve represents the digestion of 0.92 lb. of volatile garbage solids in a digestion medium of 135 lb. of digester supernatant having a total solids content of 3.51 per cent. In this test 80 per cent of the garbage volatile solids were accounted for as gas, with the yield being 12.43 cu. ft. of gas per lb. of the garbage volatile solids. The solid line curve in the graph shows the gas production trend when raw primary sewage sludge is digested. In this test 78.6 per cent of the gas was produced in the first five days, and the yield was 7.2 cu. ft. per lb. of the sewage sludge volatile solids.

The loadings in all of the tests were of the "batch" type. Cumulative loading tests are to be made in the future on both the garbage and the raw sewage sludge.

The average of seven tests made with garbage showed that 13.1 cu. ft. of gas were produced from a pound of garbage volatile solids. Without exception, the CO_2 content of the gas was higher at the beginning of the run when the gas production was greater. In digesting samples of spent brewers grain and of cheese whey it was found that the CO_2 content of the gas would rise to 60 per cent at the start of the test, and then drop sharply to a low of 20 per cent after a period of nine or ten days. This would tend to indicate that different types of garbage (due to seasonal variation of diet) might produce a large volume of gas having little fuel value in some cases.

The results of two tests made on raw sewage sludge gave an average of 8.26 cu. ft. of gas per lb. of volatile solids digested. In actual plant operation during the winter months when garbage loadings are low, the yield from garbage and sewage sludge together was 8.12 cu. ft. per lb. of volatile solids. As the actual amount of garbage handled during this part of the year is less than two tons per day, it could be assumed that this value would largely represent gas generated from sewage sludge only.

The tests made to date would tend to indicate that a given weight of volatile material in garbage would produce a greater volume of gas than a similar weight of volatile solids found in sewage sludge. Further investigation is necessary, however, before definite conclusions can be drawn.

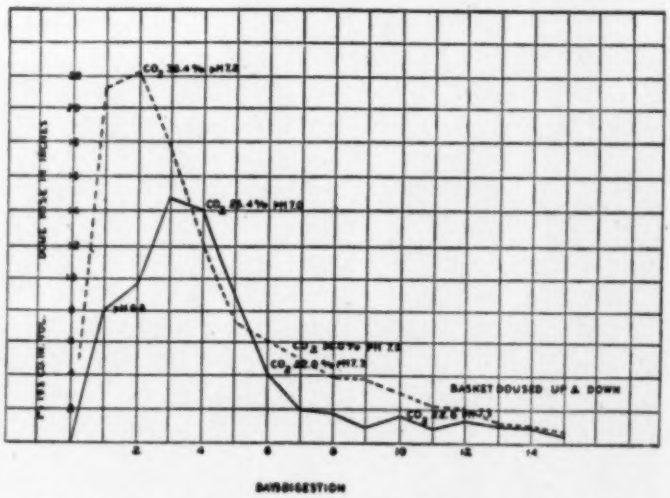


Fig. 9.—Comparison of Results from Garbage and Sludge Digestion Experiments.

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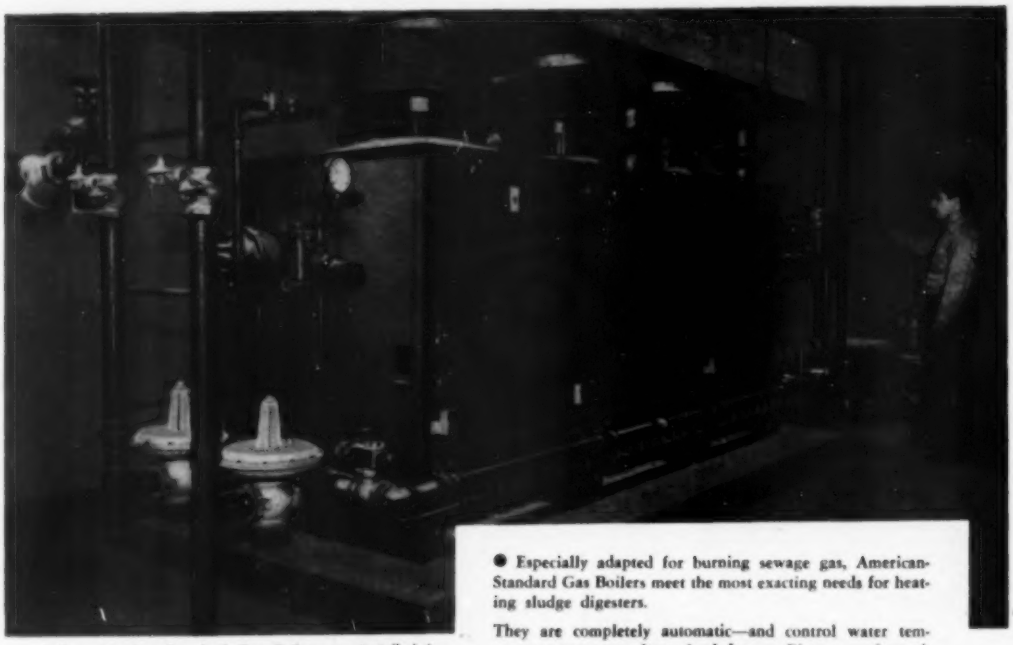

▲ Two American-Standard Gas Boilers are installed in the Northeast Sewage Treatment Plant, Philadelphia, Pa.

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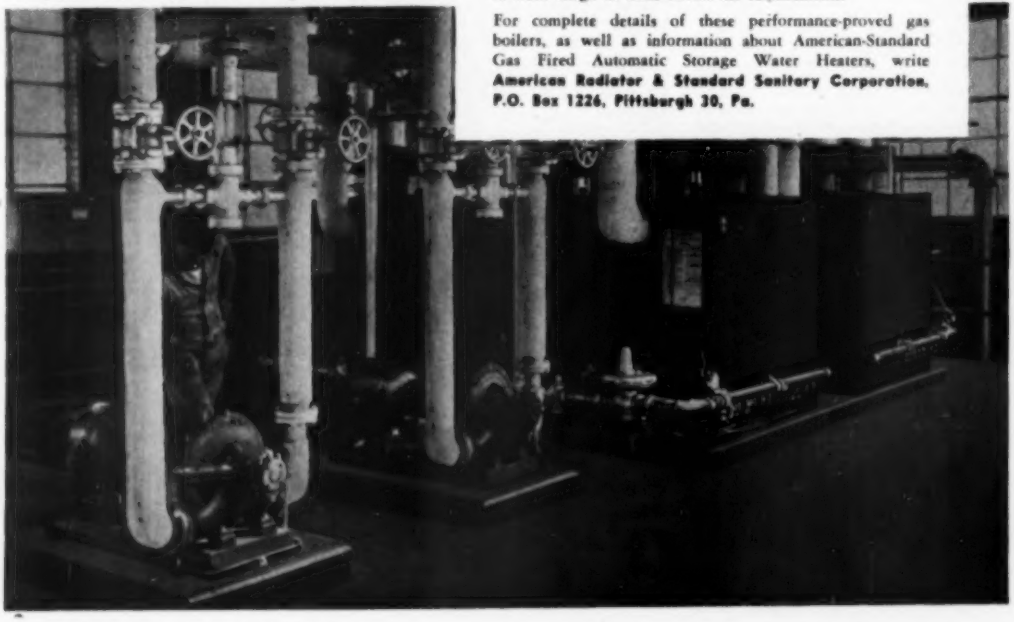

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BOILER NO.		OUTPUT PER HOUR			INPUT PER HOUR		BOILER SPACE		
Steam	Water	BTU per Hour	Sq. Ft. Steam A.G.A. Rating	Sq. Ft. Water A.G.A. Rating	BTU per Hour	Cu. Ft. 700 BTU Sludge Gas	Over-all Hgt. xx	Floor Space	
								Width	Depth
	1-GA-4E	31,500		210	39,375	56	40½	16	19¼
	1-GA-5E	42,000		280	52,500	75	40½	16	22¼
	1-GA-6E	52,500		350	65,600	94	40½	16	25¼
	2-GA-4E	63,000		420	78,750	113	54⅛	16	19¼
	2-GA-5E	84,000		560	105,000	150	54⅛	16	22¼
	2-GA-6E	105,000		700	131,250	188	55½	16	25¼
	2-GA-7E	126,000		840	157,500	225	55½	16	28¼
	4-GA-8E	147,000		980	183,750	263	54	16	37⅛
	4-GA-9E	168,000		1,120	210,000	300	54⅝	16	40⅛
	4-GA-11E	210,000		1,400	262,500	375	54⅝	16	46⅛
0-GS-4E		61,200	255		76,500	109	53⅛	16	33¼
0-GS-5E		81,600	340		102,000	146	53⅛	16	37¼
0-GS-6E		102,000	425		127,500	182	54⅛	16	41¼
1-GS-4	1-GW-4	144,000	600	960	180,000	258	57⅝	19	25
1-GS-5	1-CW-5	192,000	800	1,280	240,000	343	59⅛	23	25
1-GS-6	1-GW-6	240,000	1,000	1,600	300,000	429	60⅛	27	25
1-GS-7	1-GW-7	288,000	1,200	1,920	360,000	517	62⅝	31	25
1-GS-8	1-GW-8	336,000	1,400	2,240	420,000	600	63¼	35	25
1-GS-9	1-GW-9	384,000	1,600	2,560	480,000	686	65	39	25
1-GS-10	1-GW-10	432,000	1,800	2,880	540,000	771	65⅝	43	25
4-GS-6	4-GW-6	480,000	2,000	3,200	600,000	857	74⅞	27	41½
4-GS-7	4-GW-7	576,000	2,400	3,840	720,000	1029	76⅝	31	41½
4-GS-8	4-GW-8	672,000	2,800	4,480	840,000	1200	78⅛	35	41½
4-GS-9	4-GW-9	768,000	3,200	5,120	960,000	1372	79⅞	39	41½
4-GS-10	4-GW-10	864,000	3,600	5,760	1,080,000	1573	81⅝	43	41½
4-GS-11	4-GW-11	960,000	4,000	6,400	1,200,000	1715	83	47	41½
4-GS-13	4-GW-13	1,152,000	4,800	7,680	1,440,000	2060	76⅝	27	41½
4-GS-15	4-GW-15	1,344,000	5,600	8,960	1,680,000	2400	78⅛	31	41½
4-GS-17	4-GW-17	1,536,000	6,400	10,240	1,920,000	2740	79⅞	35	41½
4-GS-19	4-GW-19	1,728,000	7,200	11,520	2,160,000	3086	81⅝	39	41½
4-GS-21	4-GW-21	1,920,000	8,000	12,800	2,400,000	3425	83	43	41½
4-GS-22	4-GW-22	2,016,000	8,400	13,440	2,520,000	3600	78⅛	47	41½
4-GS-25	4-GW-25	2,304,000	9,600	15,360	2,880,000	4120	79⅞	61⅛	41½
4-GS-28	4-GW-28	2,592,000	10,800	17,280	3,240,000	4625	81½	69⅛	41½
4-GS-31	4-GW-31	2,880,000	12,000	19,200	3,600,000	5145	83	77⅛	41½
4-GS-33	4-GW-33	3,072,000	12,800	20,480	3,840,000	5480	79⅞	85⅛	41½
4-GS-37	4-GW-37	3,456,000	14,400	23,040	4,320,000	6165	81½	93⅛	41½
4-GS-41	4-GW-41	3,840,000	16,000	25,600	4,800,000	6850	83	103½	41½
								115½	41½
								127½	41½
								139½	41½
								153¾	41½
								169¾	41½
								185¾	41½

xx To top of Draft Hood

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PNEUMATIC GRIT WASHER AND EJECTOR

By NELSON M. FULLER
Superintendent, Water Works and Sewerage
Olean, N. Y.

THE removal of grit at the Olean Sewerage Treatment Plant is a very important detail of plant operation. Large quantities are received from storm drainage and from railroad repair shops. Also large amounts of sewage solids settle out in the grit chamber. Former methods of removal by hand, chain hoist and truck followed by burial were very disagreeable, being akin to cleaning out a large privy each week.

Formerly six man-days were required to carry out this operation, whereas the air lift system now in use washes the grit and disposes of it in thirty minutes. A mechanical conveyor system proposed for the removal of the grit would have cost $5,000. Using scrap materials and our own welders the air-lift pumping equipment herein described cost under $100.

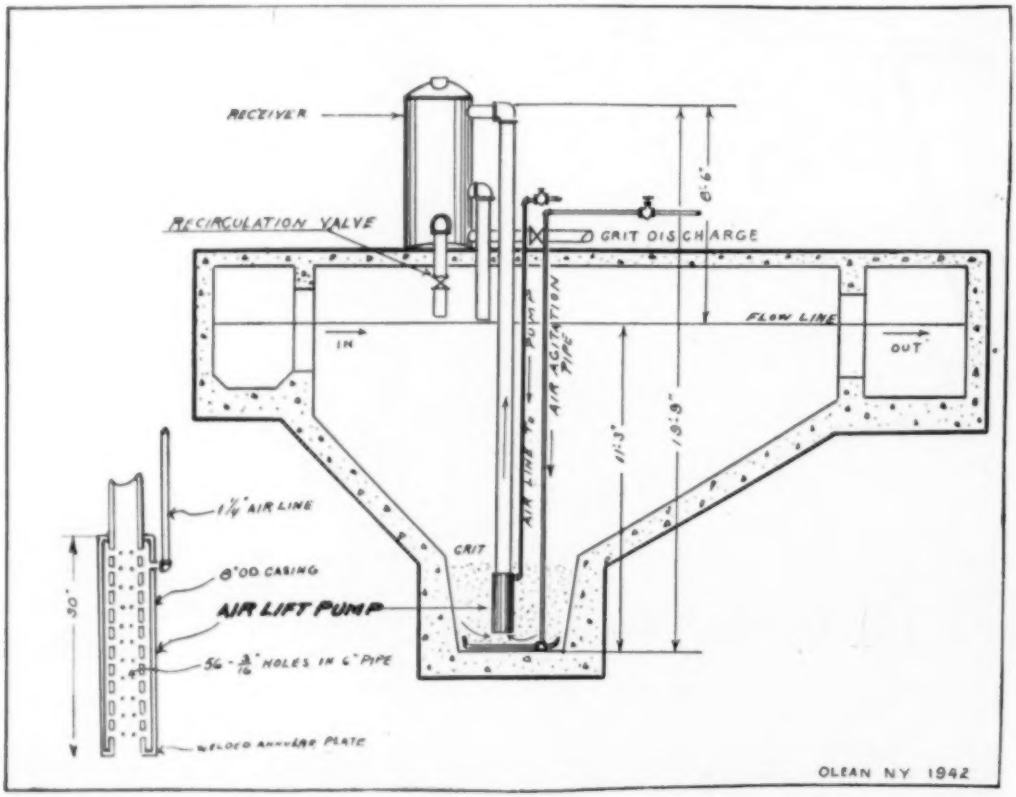
The air-lift system was limited in design to the use of air from our own portable air compressor of 105 cubic foot capacity. This permitted the use of a six inch flow pipe. An air lift pump is simple to construct after the correct size pipe is found which will give a uniform flow without "blowing through." The air water mixture must have a velocity upwards of ten feet per second. The foot-piece (the air and water mixing device) was designed so that in this case no obstruction to the free flow of grit, small sticks, and the rags which sometimes pass the bar screen could get fouled at the entrance.

The sketch accompanying this description shows a detail of the foot piece, which was made by boring fifty-six three-sixteenth holes in a thirty inch section of six inch pipe. This section of pipe was then placed into a piece of eight inch pipe and welded at both ends. The one and one-quarter inch air line was connected into the eight inch casing. A small tank was picked up as junk and was used for the air and water separator or receiver.

It will be observed from the sketch that the grit discharge line from the receiver can be closed and that the grit and solids can be recirculated to secure any desired period of washing action in the grit chamber proper. After a suitable period of washing the grit is allowed to settle and the sewage solids which are then in suspension in the grit chamber are flowed into the settling tanks. When this is completed the washed grit is removed by the air lift pump and discharged to the point of final disposal, which in our case is the Allegany River.

In order to clean out the corners of our grit chamber and to hold sewage solids in suspension air jets have been arranged to agitate the grit in these areas.

There is an excellent paper on this type of air lift adaptation in Sewage Works Journal, Volume V, No. 3, pages 509-522, by H. Blunk, Engineer, The Emscher Genossenschaft, Essen, Germany, titled "A Contribution to the Design of Grit Chambers," translated by G. P. Edwards of New York.



SLUDGE LAGOONING

By DON E. BLOODGOOD
Assoc. Prof. of Sanitary Engineering, Purdue University

THE deep-pit sludge digestion at Indianapolis was first reported on by Calvert in 1928.[1] This method of sludge digestion had then been in use for two years. At the outset, Indianapolis expected to use "sludge lagoons" or "deep-pit sludge digestion" only as a temporary measure until some other process could be decided upon. The pilot plant tests on fertilizer production in 1931 indicated quite conclusively that this means of sludge disposal was not sufficiently lucrative to warrant competition with Milwaukee, Houston and Pasadena in their sludge marketing enterprises.

The Indianapolis sludge lagoons met the needs for sludge disposal inasmuch as it was possible to handle all sludge produced at the Indianapolis treatment works without odor or other nuisance. There being ample area for additional deep lagoon construction, and because lagoons could be built at a relatively small cost, it seemed advisable to continue this method of handling sludge until a more suitable or economical process could be found.

Sludge lagoons have been used continuously at Indianapolis without creating nuisance for the past 20 years. It is believed that such sludge disposal economy has been the explanation, in a large part at least, for the low unit cost of sewage disposal.

Although sludge lagooning cannot be considered as a satisfactory method for sludge disposal for all installations, in many cases it can be used to meet emergencies which arise.

Sludge lagooning can be carried out successfully, but the operation must be as carefully supervised as any other part of the sewage treatment process. A sludge lagoon operated on the same basis as the old refuse dump will be just as unsatisfactory as these old dumps were, but if they are operated with common sense plus some pride the result will show as much improvement as the "sanitary fill" method of refuse disposal does over the old dump.

Locations of Lagoons

The lagoon area at Indianapolis is located in the flood plain between White River and Eagle Creek. Most of the lagoons have sand bottoms, as most of the top soil was used in constructing the levees forming the pits. The bottoms of the pits are only 6 to 8 feet above the ground water at minimum ground water elevations, and during flood stages the ground water is often above the pit bottoms. Although many of the lagoons have sand bottoms, there seems to be very little seepage into the ground once there is sufficient sludge in a lagoon to cover the bottom. In the early days numerous attempts were made to loosen or scarify the bottoms between cycles of operation so that the seepage would be increased. In later years, however, the amount of drainage through the bottom of the lagoon was thought to be only minor in nature. All excess water was either allowed to overflow at the top to adjacent pits or was removed with portable pumps when a lagoon was being dewatered.

Construction of Lagoons

In constructing the lagoons the top soil which could be reached with a 20-foot boom was removed with a clamshell bucket and caterpillar crane which piled it as a levee just wide enough at the top for a path. The levees were about 12 feet high and the natural slope assumed was about one foot vertical and one and one-half horizontal. In the early construction very little attention was given to leveling the bottom or even removing stumps of trees in some of the pits. In later years when the sludge was removed from some of these crudely constructed lagoons, considerable difficulty was encountered, so that when the WPA days came along a project was instigated for leveling the bottoms of the lagoons, removing stumps, and increasing the width of levees so that they could be used as roadways.

The smallest lagoon now in service is about 300x325 feet. The lagoon No. 8 on the map (Fig. 1) was originally three lagoons, but the north and south levees were removed to make the larger unit. Experience has shown that the area of a lagoon is not too important. The most desirable area for a single lagoon will depend upon the total amount of sludge to be disposed of at any particular plant.

In planning lagoons, where the sludge must eventually be removed, it is desirable to have the tops of the levees wide enough for truck traffic. Lagoons which must be emptied should be built with an earth ramp having a slope such that the available trucks will have no difficulty in climbing it with their maximum load. Some of the ramps at Indianapolis have at least 15 per cent grades. Cinder roadways are maintained on the bottoms of the lagoons as the sludge removal progresses.

TABLE I

Character of Sludges Pumped to Lagoons

	Primary Sludge Per Cent			Activated Sludge Per Cent			Plain Aeration Sludge Per Cent		
	Solids	Volatile	Nitrogen as N	Solids	Volatile	Nitrogen as N	Solids	Volatile	Nitrogen as N
1935....	4.42	78.7	2.82	2.78 0.41*	63.6	4.58	4.32	69.7	3.96
1936.....	4.84	74.8	2.88	2.78 0.64*	63.9	4.80	4.58	68.7	3.79
1937.....	4.25	71.1	2.48	1.69 1.04*	64.0	4.30	4.11	66.2	3.26
1938.....	5.15	72.4	2.47	2.58 1.08*	64.2	4.59	4.45	64.8	3.40
1939.....	5.84	68.4	2.58	0.89*	61.6	4.61	3.82	65.3	3.31
1940.....	5.83	62.1	2.45	0.79	60.2	4.45	3.53	62.7	3.76
1941.....	6.27	68.2	2.63	0.78*	63.5	4.39	3.54	65.5	3.44
1942.....	7.04	69.1	2.58	0.92*	66.0	4.72	4.44	65.0	2.99
Avg...	5.45	70.5	2.62	2.46 0.82*	63.5	4.56	4.10	66.0	3.49

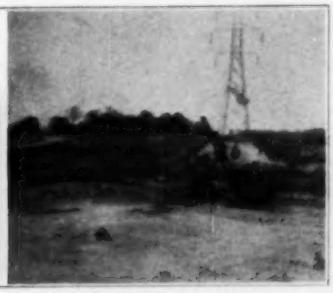
*Concentration of return sludge. Some sludge was wasted at this concentration; the remainder was concentrated to the higher figure in a sludge concentration tank.

Sludge Distribution and Supernatant Drains

The sludge is distributed to the lagoons through steel pipes laid about three to four feet deep in the levees. From the plant to the lagoons the main piping is 12 inches in diameter. The distribution lines are 8 and 10 inches with gate valves on branches leading horizontally into each of the four corners of a lagoon wherever possible. Eighteen-inch tile is used for the valve boxes. There have been only a few instances where freezing caused any trouble

Starting a Lagoon
Discharge line extending into lagoon

Lagoon Partially Filled



Sludge Being Removed
Lagoon nearly clean

with valves set in these boxes. The discharge lines beyond the valves extend into the lagoons about 20 feet beyond the face of the levees. No particular attention has ever been given to the grades on which the pipelines have been laid, consequently draining of the lines taken out of use was not possible. Caking of sludge in the lines, when not in use, has never been a problem. Stoppages which have occurred have usually been removed by blowing compressed air through the lines containing sludge. Appreciable coatings of grease were found in some of the lines when skimmings from the primary tanks were being disposed of by pumping them to the lagoons. The skimmings caused no particular difficulty in the lagoons, however.

A large percentage of the distribution system has been made up of second-hand steel or wrought iron pipe and it has served very well. The most recent extension to the distribution system was made with a 10-inch, 3/16-inch wall, tar coated, steel pipe with plain ends and in 40-foot lengths. The lengths of this pipe were connected by electric welds and dropped into the trench after welding.

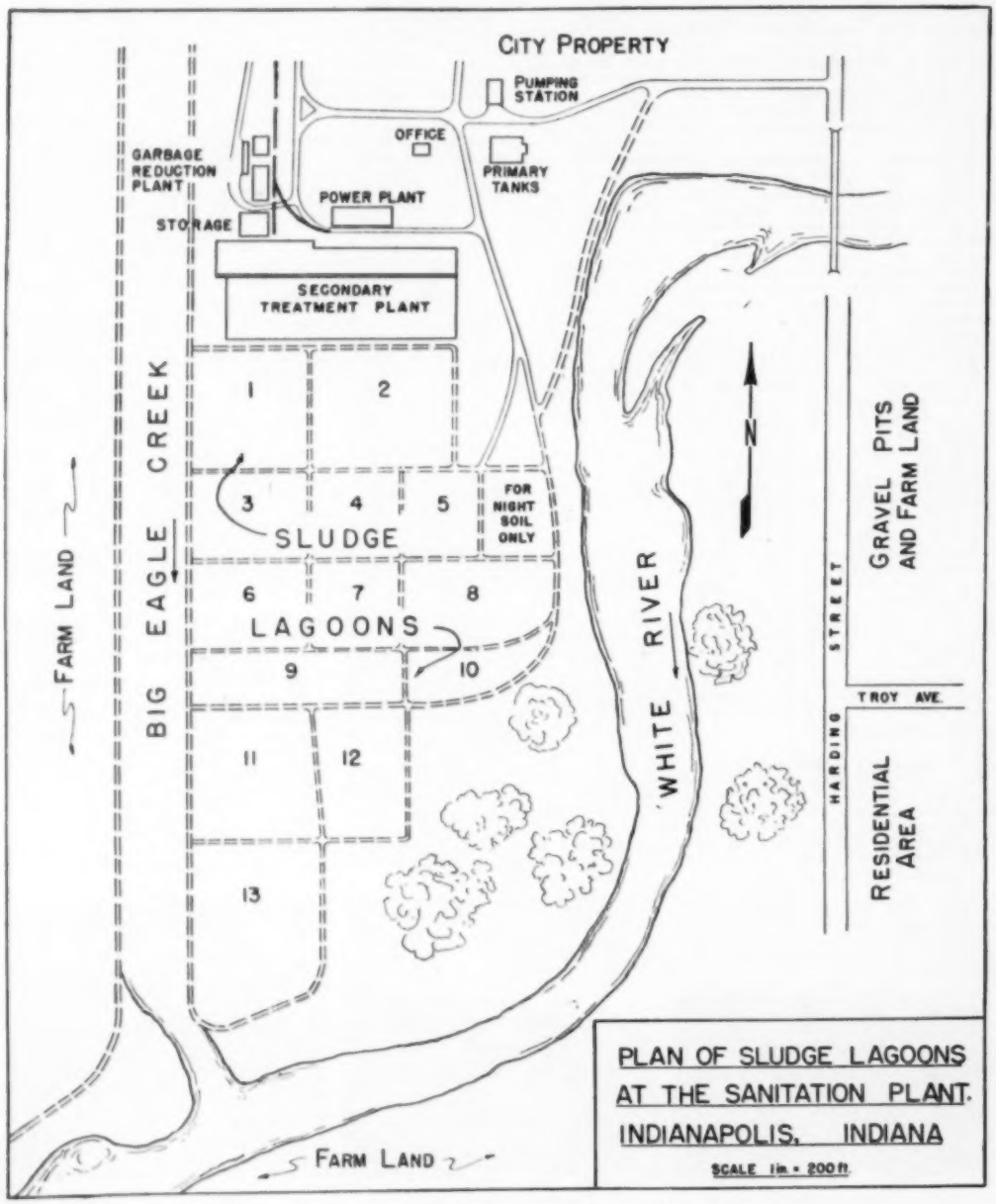


Fig. 1.—Plan of Sludge Lagoons at Indianapolis Sewage Treatment Plant.

No attempt has been made to return the supernatant to the sewage plant. Operation of the lagoons in recent years has shown that if the supernatant flows through several lagoons and finally into one containing practically no sludge, the overflow from this last lagoon will be entirely satisfactory for discharge into the receiving stream. Supernatant or sludge is drawn from one lagoon to another through pipes placed across the levees at about a depth of 3 feet. No valves are used on these lines. The flow through them can be stopped or controlled by placing a short length of plank over the end of the pipe on which the highest water head exists. The most satisfactory drainage arrangement was found to be the installation of a box at each end of these drain lines (Fig. 2). These boxes are usually approximately 2½ feet square by 5 feet deep, and anchored in the side of the levee with posts. The boxes are provided with removable boards on the outside so that the elevation of the liquid in the lagoons can be controlled.

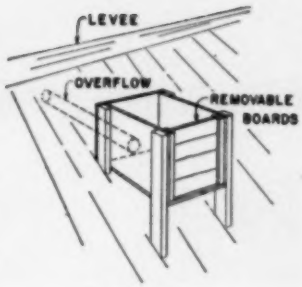


Fig. 2.—Drain Box

From the experience gained over the years, it has been definitely concluded that an underdrain system is not necessary for the satisfactory operation of lagoons.

Operation and Control

The solids digested in the lagoons were primary, activated, and plain aeration sludges (Table I). No effort was ever made to thoroughly pre-mix the solids of the several sludges as they were pumped into the lagoons. At two periods lasting for several months both ground and unground garbage, amounting to the entire garbage from the city, was satisfactorily digested in the lagoons along with the sewage solids.

No routine laboratory control was established to aid in the operation of the lagoons. In 1933 a composite of sludge being removed from the lagoons was made and the analysis of this composite is given in Table II. This does not mean, however, that a lagoon can just be built and used as a dump for all solids and still maintain satisfactory digestion without the production of objectionable odors. Great care has always been taken in the addition of raw solids so that excessive amounts were never added in short periods of time.

TABLE II

Digested Sludge Chemical Examination Composite Sample for 1933

Analysis	Per Cent
	Dry Solids Basis
Volatile	48.3
Total organic nitrogen	2.34
Petroleum ether soluble	6.65
Phosphoric acid (P_2O_5)	1.72
	Ash Basis
HCl insoluble	23.12
SiO_2	16.85
Fe_2O_3	4.00
Al_2O_3	9.52
$CaCO_3$	22.97
$MgCO_3$	3.19
SO_3	2.68

It is desirable to have several lagoons into which sludges can be pumped so that one may be used for several days and then left to stand idle for a few days so that decomposition and separation of solids and liquid can take place. This procedure would not necessarily have to be followed if the lagoon were large enough so that there was a sufficient amount of digested sludge to assimilate and buffer the raw solids being added.

In starting a lagoon it is desirable to fill it with supernatant or digested sludge to a depth of three or four feet before any raw solids are added. The addition of sludge goes on for many months and an effort is made to add solids until it is impossible to add more without the sludge flowing on through to the overflow.

It has been impossible to run solids balances on the lagoons because of the overflowing from one to the other unit, and because of the difficulty in keeping records when changes from one lagoon to another take place during a pumping period. The information on the total pounds of raw solids digested in the lagoons during a sixteen-year period is given in Table III along with the lagoon volume available. It is apparent from these data that solids have been digested at the rate of about six pounds per cubic foot per year.

When a lagoon has been filled completely with sludge it is "laid by" for as long a period as possible before an attempt is made to remove the sludge. It has been found that a sludge lagoon "laid by" for 18 months results in a material with a moisture content as low as 75 per cent. During the 18 months' digesting and dewatering period a portable pump is used to remove free water which will accumulate at the low points in the sludge bed.

When the sludge is ready for removal a motor crane with clamshell bucket and caterpillar treads is brought to the lagoon at the point where the ramp descends from the levee road. The operator then starts loading the sludge onto the trucks of market gardeners who haul it away for fertilizer. The sludge is usually six to eight feet deep when the unloading of the lagoon starts. By the time the shovel has worked its way to the bottom of the ramp the sludge surface has settled with a slope toward the ramp. A hole is then dug in the bottom to serve as a sump for the

TABLE III

Dry Solids Wasted to Lagoons—Pounds per Year

Year	Primary Sludge	Activated Sludge and/or Plain Aeration Sludge	Total	Average Lagoon Volume in Cu. Ft. in Service	Pounds per Cu. Ft. per Year
1926	14,515,000	12,389,000	26,904,000	4,368,000	6.15
1927	14,560,000	10,812,000	25,372,000	4,[illegible],000	5.80
1928	13,536,000	9,942,000	23,778,000	5,562,000	4.26
1929	16,254,000	6,103,000	22,357,000	5,562,000	4.01
1930	17,242,000	10,504,000	27,746,000	5,562,000	4.98
1931	19,024,000	13,418,000	32,442,000	6,398,000	5.07
1932	16,742,000	13,706,000	29,448,000	8,306,000	3.54
1933	13,617,000	17,857,000	31,474,000	9,942,000	3.17
1934	14,983,000	20,236,000	35,219,000	9,942,000	3.54
1935	18,706,000	20,241,000 [1] 1,590,000	40,537,000	9,942,000	4.08
1936	16,998,000	19,045,000	36,043,000	12,238,000	2.95
1937	16,239,000	22,508,000	38,747,000	14,150,000	2.74
1938	15,090,000	30,539,000	45,629,000	14,150,000	3.23
1939	16,519,000	28,585,000	45,104,000	14,150,000	3.19
1940	22,752,000	30,799,000	53,551,000	24,220,000	2.21
1941	24,695,000	30,939,000	55,634,000	24,220,000	2.30
1942	30,907,000	35,006,000	65,913,000	24,220,000	2.72

[1] Activated sludge.

Location of Lagoons in Relation to Plant in Background

Lagoon Being Filled Supernatant still plentiful.

Overflow Box in Operation Sludge and supernatant liquor at high level.

Winter Scene of Lagoon
Surface partly frozen. Cones caused by gas.

Lagoon Being Dried Out
Sludge approximately 8 ft. deep.

Lagoon Being Dried Out
Growth of weeds on sludge surface.

portable pump, which removes water leaving the sludge and also rain water.

Table IV is a tabulation of the yardage of sludge removed during the past several years and cost of such removal.

The removal and disposal of the sludge from the lagoons in a layout as large as that at Indianapolis is a great problem. It is entirely possible that a portable dryer and incinerator might be built which could be moved into a lagoon for the disposal of all sludge that could not be given away to farmers and market gardeners. If such an arrangement could be made or the sludge could be given away or sold sufficiently fast to completely clean one lagoon per year, it would effectively decrease the volume of lagoon capacity needed to meet the requirements of a city.

General Discussion

Sludge digestion lagoons can be operated without objectionable odors providing sufficient seeding and buffering material is added when a lagoon is being started and the amount of raw solids added each day is not more than can be readily assimilated and decomposed. In the operation of lagoons it is necessary to discontinue the addition of raw solids upon the detection of the slightest objectionable odor. During the cold months great care must be exercised, as it is possible to overload the lagoons during that season without producing bad odors, but when warmer weather comes and fermentation is accelerated, odors will appear because of the overbalance of "green" solids during the period of retarded digestion.

In some instances appreciable depths of scum form on the lagoons and there seems to be no objection to this unless it is because of the weeds that may grow in the scum. It is recommended, however, that the levees be kept free of weeds insofar as possible because it creates a feeling that the lagoons are definitely a part of the sewage disposal plant rather than uncared-for dumps.

During the summer months many rat-tailed maggots grow in the lagoons. If the flies from these maggots should be a problem it is believed that they could be satisfactorily controlled by the use of light oil films or some of the newer materials used for insect control.

Lagoons of more than five feet in depth are, of course, a hazard, and if they are not sufficiently isolated they should be properly fenced.

The cost of operation of the lagoons can be seen from Table IV.

These cost figures do not include interest or depreciation and they are based upon the sewage flow that was given primary treatment. Not all of the sewage was given complete treatment during these years.

Conclusions

1. A mixture of primary sludge, activated sludge, plain aeration sludge, and garbage can be satisfactorily digested without odors in open lagoons.
2. If the lagoons are used for digestion only, at least six pounds of solids can be digested per year per cubic foot of lagoon capacity. This is equivalent to 0.17 cu. ft. of lagoon capacity per pound of solids.
3. If the lagoons are used for digestion and also as dewatering beds, a capacity of 0.37 to 0.40 cubic feet per pound of raw solids per year is sufficient, providing the air-dried sludge can be removed as rapidly as it is ready for hauling.
4. Using the above capacities, it is possible to discharge a supernatant of good quality to the receiving stream.

Reference

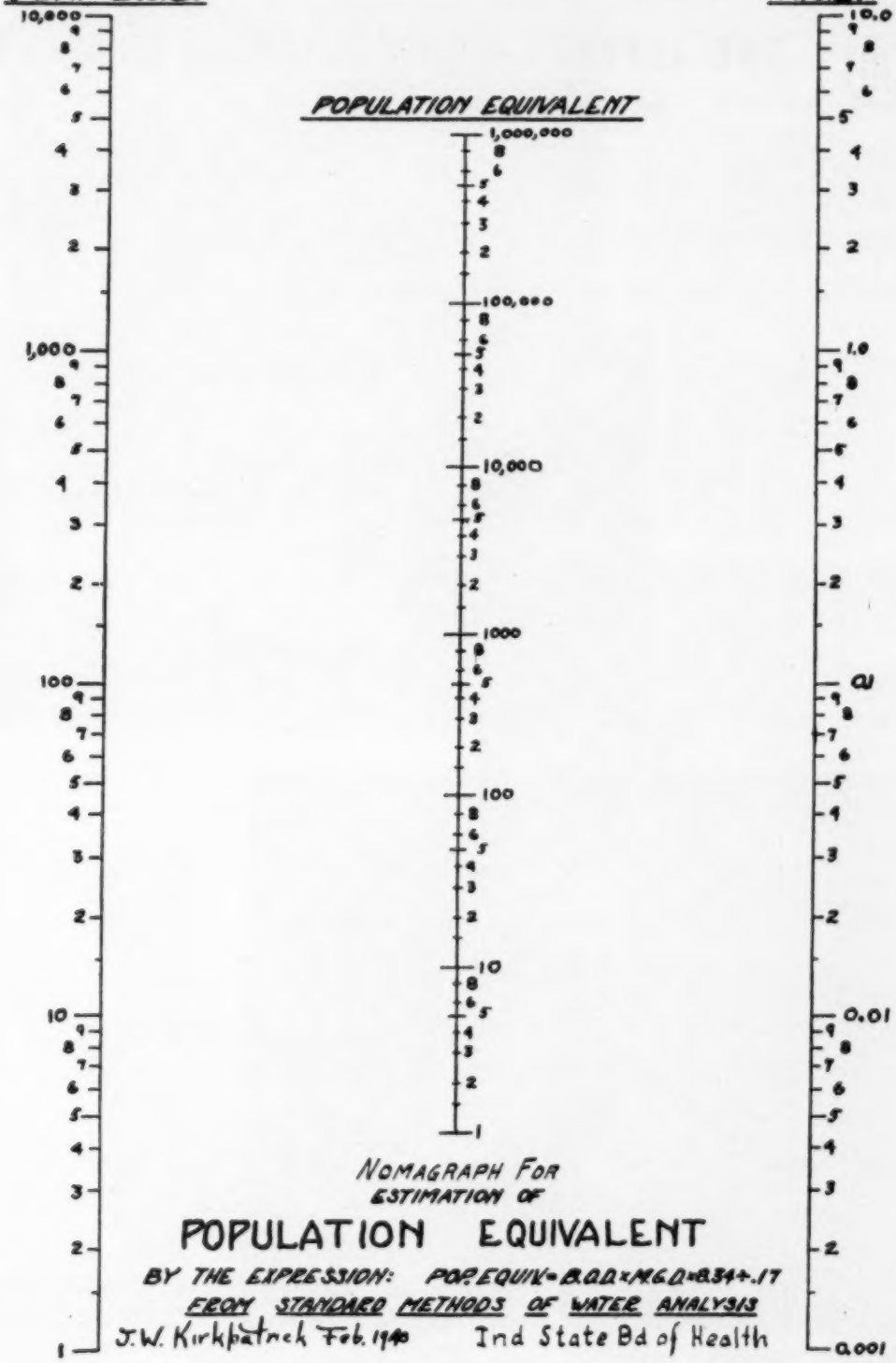
[1]*Engr. News Record*, Feb. 9, 1928.

TABLE IV

Digested Sludge Removed and Cost of Operation of Lagoons

Year	Cubic Yards	Cost per Mil. Gal. of Sewage Given Primary Treatment*
1926	.....	$0.96
1927	5,000	1.68
1928	10,000	0.68
1929	16,128	0.61
1930	14,336	0.58
1931	23,616	0.51
1932	12,438	0.26
1933	5,224	0.30
1934	20,208	0.23
1935	13,129	0.23
1936	25,819	1.09
1937	9,343	0.39
1938	12,198	0.20
1939	35,050	0.31
1940	25,128	0.48
1941	17,077	0.57
1942	14,578	0.42
Average	.....	$0.56

*No capital charge, interest, or depreciation included.



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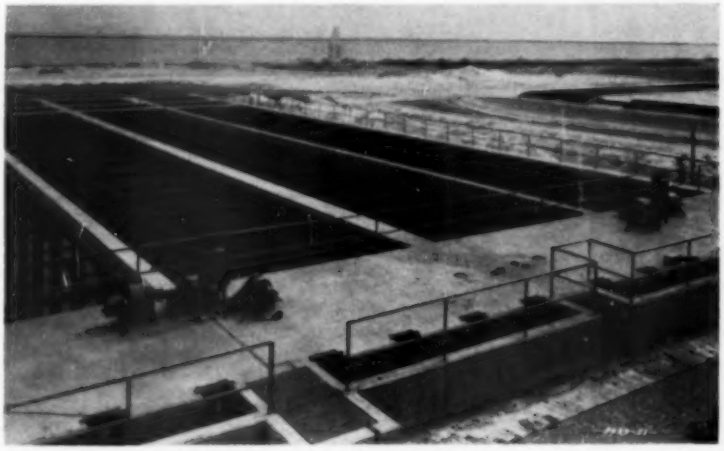
The Kilbourne & Jacobs Mfg. Co., Columbus, Ohio

A complete line of equipment for Water, Sewage and Industrial Waste Treatment as well as Biofiltration Systems for Purification of Sewage and Concentrated Organic Wastes: Bar Screens, Grit Washers (patented), Grit and Sludge Collectors (patented), FLOCTROLS (R) (slow-mixing equipment) (patented), Sludge Elevators, Screenings and Garbage Grinders (patented), Conveyors, Chains, and Bearings.



View at right shows a portion of the primary settling tanks in the new Tampa, Florida Sewage Treatment Plant.

View at left shows the 26th Ward Treatment Plant, New York City. Each channel is equipped with a Jeffrey scraper type Grit Collector and V-bucket type Elevator.

The Jeffrey Manufacturing Company of Columbus, Ohio, is prepared to grant licenses to all ultimate consumers for a reasonable royalty obtainable upon application, under any or all of its patents.

Jeffrey Mechanically Cleaned Bar Screens

View at left shows 2 Jeffrey coarse, back-cleaned type screens at the 26th Ward Sewage Treatment Works, New York City. Based on a new principle of design this type of Jeffrey Mechanically Cleaned, Coarse Bar Screen is practically fool-proof. Two fine screens are shown in background.

Screen Bars may be of Round or Rectangular cross-section.

Operation by time control is recommended but also can be by differential float. Provision is made for continuous operation if desired.

Jeffrey **JIGRIT** Washer

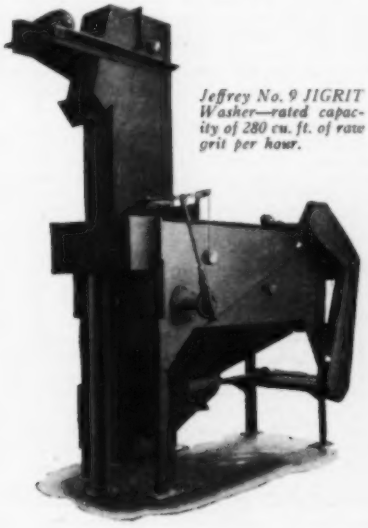
(REG. U. S. PAT. OFFICE)

Jeffrey patented JIGRIT Washer is now built in three sizes ranging in capacity from one ton to fourteen tons per hour, offering these advantages:

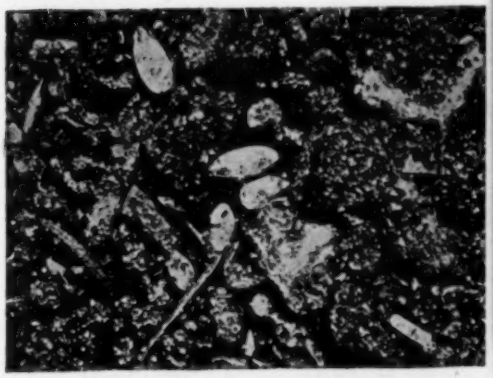
1—Removes 90% of putrescible solids.

2—Washed grit contains no organic seeds or unsightly material—can be used as fill without creating a nuisance.

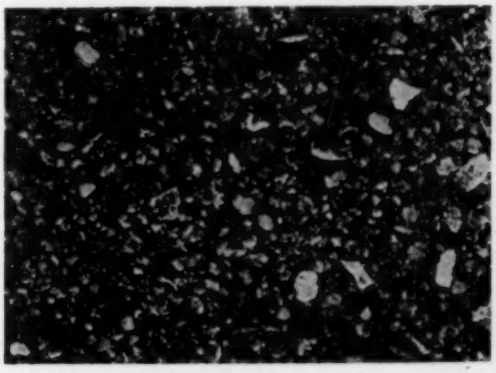
3—Recovers practically all of the +65 mesh grit.



Jeffrey No. 9 JIGRIT Washer—rated capacity of 280 cu. ft. of raw grit per hour.



Magnified view of unwashed sewage grit



Magnified view of washed grit after passing through Jeffrey JIGRIT Washer

A LUBRICATION CHECK SHEET

By ROBT. C. URBAN
San. Engr., Corps of Engrs., War Department

THE Lubrication Check Sheet shown below will be of help in normal times of operation as well as when adverse conditions prevail.

There are three steps in setting up a lubrication check sheet.

1. Locate every piece of equipment needing grease or oil as a lubricant or as protection.

2. Study the manufacturers maintenance instructions to determine where and when to lubricate and what kind of lubricant to use. Inasmuch as many manufacturers have particular preferences in the matter of lubricants, this may lead to a large number of different types of lubricants and as many grease guns.

It may be much simpler to call in a lubrication engineer from any of the recognized oil companies and have him prepare a lubrication specification sheet for every point of lubrication you have listed.

In this way it may be possible to cut down on the number of oils and greases that will have to be stocked. As few as two oils and two greases may suffice.

3. Prepare the Lubrication Check Sheet following the general idea of the accompanying illustration. List all of the units needing lubrication, the necessary lubrication points, the type of lubricant recommended for each point. Allow space for date of lubrication and initials of operator performing the job.

There is no doubt that the Lubrication Check Sheet will become more and more important to the proper maintenance of operating equipment.

MASTER LUBRICATION CHECK SHEET

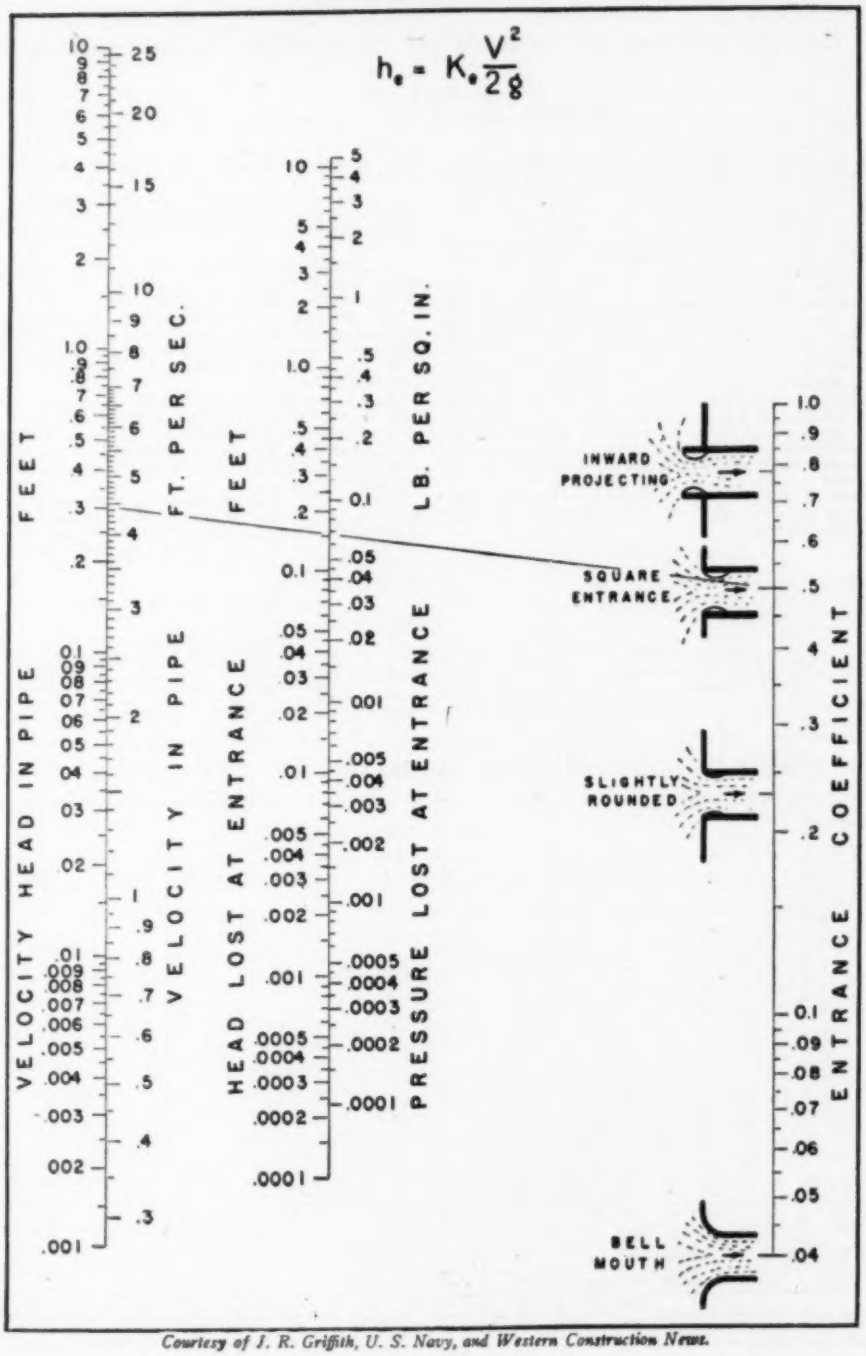
1945

GREASE: "HEAVY" - X CO. NO. 2 HEAVY DUTY
"CUP" - X CO NO. 31 CUP GREASE

OIL: "20"-X CO. NO. 341 S.A.E. 20
"90"-X CO. GEAR OIL 90

UNIT	FITTING TYPE	FITTING NO.		TYPE OF OIL OR GREASE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SEWAGE PUMP HOUSE																
SEWAGE MOTORS (2) BEARINGS	PIN	2 EA.	G	"HEAVY"												
SEWAGE PUMPS (2) BEARINGS	PIN	2 EA.	G	"HEAVY"												
GREASE SEALS (2)	PRESSURE CUP	1 EA.	G	"CUP"	→		CHECK DAILY & ADD AS REQUIRED									
VACUUM MOTOR BEARINGS	PIN	2	G	"HEAVY"												
VACUUM PUMP	SIGHT FEED	1	O	S.A.E. 10	→		CHECK DAILY & ADD AS REQUIRED									
FLOAT RODS (2)	"SURFACE"	1 EA.	O	"20"	1 TIME	1 TIME	1 TIME	1 TIME								
SCREENINGS GRINDER																
GEAR REDUCER	PLUG	1	O	"20"	CHANGE				CHANGE				CHANGE			
(• -)	PLUG	1	O	"20"	CHECK WEEKLY & ADD AS REQUIRED - SEE WEEKLY CHECK SHEET											
LOWER SHAFT BEARING	PUSH	1	G	"HEAVY"	→				TWELVE STROKES DAILY							
MOTOR BEARING	PIN	1	G	"HEAVY"	2 TIMES											
SLUDGE COLLECTOR																
GEAR REDUCER	PLUG	1	O	"90"	CHANGE 6 TIMES						CHANGE					
(• -)	PLUG	1	O	"90"	CHECK WEEKLY & ADD AS REQUIRED - SEE WEEKLY CHECK SHEET											
SPROCKET BEARING	PUSH	1	G	"CUP"	GREASE WEEKLY								SEE WEEKLY CHECK SHEET			
MOTOR BEARING	PLUG	1	G	MANUFACTURERS SPECIAL	6 TIMES											
SLUDGE PUMP																
MOTOR BEARINGS	PUSH	2	G	"HEAVY"												
MAIN BEARINGS	PUSH	4	G	"HEAVY"	6 TIMES	4 TIMES	1 TIME	1 TIME								
ECCENTRIC BEARING	SIGHT FEED	1	O	"20"	→		CHECK DAILY & ADD AS REQUIRED									
CROSS HEAD BEARING	"SURFACE"	1	O	"20"	→		CHECK DAILY AND KEEP PIN COVERED									
GEAR REDUCER	PLUG	1	O	"90"	CHANGE 6 TIMES						CHANGE					
(• -)	PLUG	1	O	"90"	CHECK WEEKLY & ADD AS REQUIRED - SEE WEEKLY CHECK SHEET											
CONNECTING ROD	GREASE CUP	1	G	"CUP"	→			GIVE SLIGHT TURN DAILY								
TRICKLING FILTER																
BEARINGS	PIN	5	G	"CUP"	10 TIMES	10 TIMES	5 TIMES	1 TIME								
ROTARY VENTILATORS (3)																
TOP BEARING	"CUP"	1 EA.	G	"CUP"												
BOTTOM BEARING	"CUP"	1 EA.	G	GRAPHITE MARINE												
HOT WATER CIRCULATORS (2)																
MOTOR BEARING	OIL CUP	2 EA.	O	"20"	4 TIMES	4 TIMES	2 TIMES	2 TIMES								
SHAFT BEARING	GREASE CUP	1 EA.	G	MANUFACTURERS SPECIAL	4 TIMES	2 TIMES	1 TIME	1 TIME								
FLOATING COVER																
ROLLER (6) BEARINGS	PIN	2 EA.	G	"CUP"												
VALVES																
6" SCUM WELL PLUG VALVE	PLUG	1	G	PETROLEUM JELLY	→		KEEP VALVES TURNING EASILY									
OTHER 6" PLUG VALVES	PLUG	1 EA.	G	MANUFACTURERS SPECIAL	→		KEEP VALVES TURNING EASILY									
GAS LINE PLUG VALVES	PLUG	1 EA.	G	MANUFACTURERS SPECIAL	→		KEEP VALVES TURNING EASILY									
WORM STEM VALVES	"SURFACE"	1 EA.	G	"CUP"	→		KEEP STEM SURFACE COVERED									
PRESSURE RELIEF F.T. UNITS																
PRESSURE-VACUUM F.T. UNIT	LEATHER DIAPHRAM	1	O	NEATSFOOT	1 TIME		1 TIME									
FLAME TRAP UNIT (SPRING)	"SURFACE"	1	G	"CUP"	1 TIME		1 TIME									
PRESSURE F.T. UNIT	LEATHER DIAPHRAM	1	O	NEATSFOOT	1 TIME		1 TIME									
(• -) (SPRING)	"SURFACE"	1	G	"CUP"	1 TIME		1 TIME									
TELL-TALE																
CHAIN	"SURFACE"	1	G	"CUP"	1 TIME		1 TIME									
MOTORIZED VALVE																
SLIDE	"SURFACE"	1	G	"CUP"			1 TIME									
MOVING PARTS	BEARINGS	EA.	O	"90"			1 TIME									
DAMPER MOTOR																
MOTOR BEARING	"OIL CUP"	1	O	S.A.E. 10		1 TIME										
CHLORINATOR																
METAL	"SURFACE"	EA.	G	PETROLEUM JELLY	KEEP ALL METAL TUBING, VALVES, PARTS, ETC., COVERED.											

HYDRAULIC ENTRANCE LOSSES



Courtesy of J. R. Griffith, U. S. Navy, and Western Construction News.

WATER FLOW THROUGH PIPES

A Nomograph for Solving the Hazen-Williams Formula

By DONALD R. KEITH
Civil Engineer, Division of Water, Columbus, Ohio

MANY hand-books containing hydraulic data include tables for solution of the Hazen-Williams formula for flow of water in pipes. These tables are limited in their scope and give results for "V" only. Then you either figure "Q" from "V," or find some other table which shows these values.

Even with the tables it is necessary to do a certain amount of calculation, such as interpolation, etc., for seldom does your problem fit the figures in the table.

Some books contain curve charts for the solution of this formula, but only for "V." The curve charts are usually of such small scale that they are tedious to use and will not give results close enough for practical purposes since the width of a pencil point might make a very definite difference in the value of "V."

To provide a practical device for the solution of pipe discharge problems continually confronting the Division of Water and the Sewage Department of Columbus, the accompanying chart was constructed; a chart accurate enough for all practical purposes, simple enough in its operation for an individual of average intelligence to use, and furthermore, one comprehensive enough to solve every problem that had to do with the flow of water in pipes.

The Hazen-Williams formula was selected for the reason that it seems to be more generally used and accepted than any other.

To the main formula,

$$V = CR^{0.63} S^{0.54} 0.001^{0.54}$$

was added,

$$Q = AV = 4\pi R^2 V$$

in which

V = Velocity
R = Hydraulic radius
S = Slope, or loss of head
C = Coefficient.

The value of "C" depends on the material and condition of the inner surface of the pipe. (See accompanying table of "C" values.)

In laying out the R-scale, it was immediately seen that the operation of chart would be simplified by adding the pipe diameter-in-inches-scale to the opposite side of the line by the formula R = D/4.

The Q-scale was first laid off for discharge in cubic feet per second, then to simplify, a scale showing discharge in gallons per minute was added to the opposite side of line.

The scale-modulus for the R and S-scales is 8, that is to say, the logarithmic cycle for each of these scales would equal that of an 8-in. slide rule, in the original size of chart as constructed; in the C-scale the cycle is 6.84-in.; the V-scale, 3.42-in.; and the Q-scale, 1.844-in.

The S-scale is graduated in decimals of one foot to the lineal foot. In problems involving loss of head, such as one foot loss of head in a thousand lineal feet, use the point 0.001 on the S-scale, and move the decimal period three places to the right (1.00). The S-scale is used for slope, loss of head, and pressure expressed in feet.

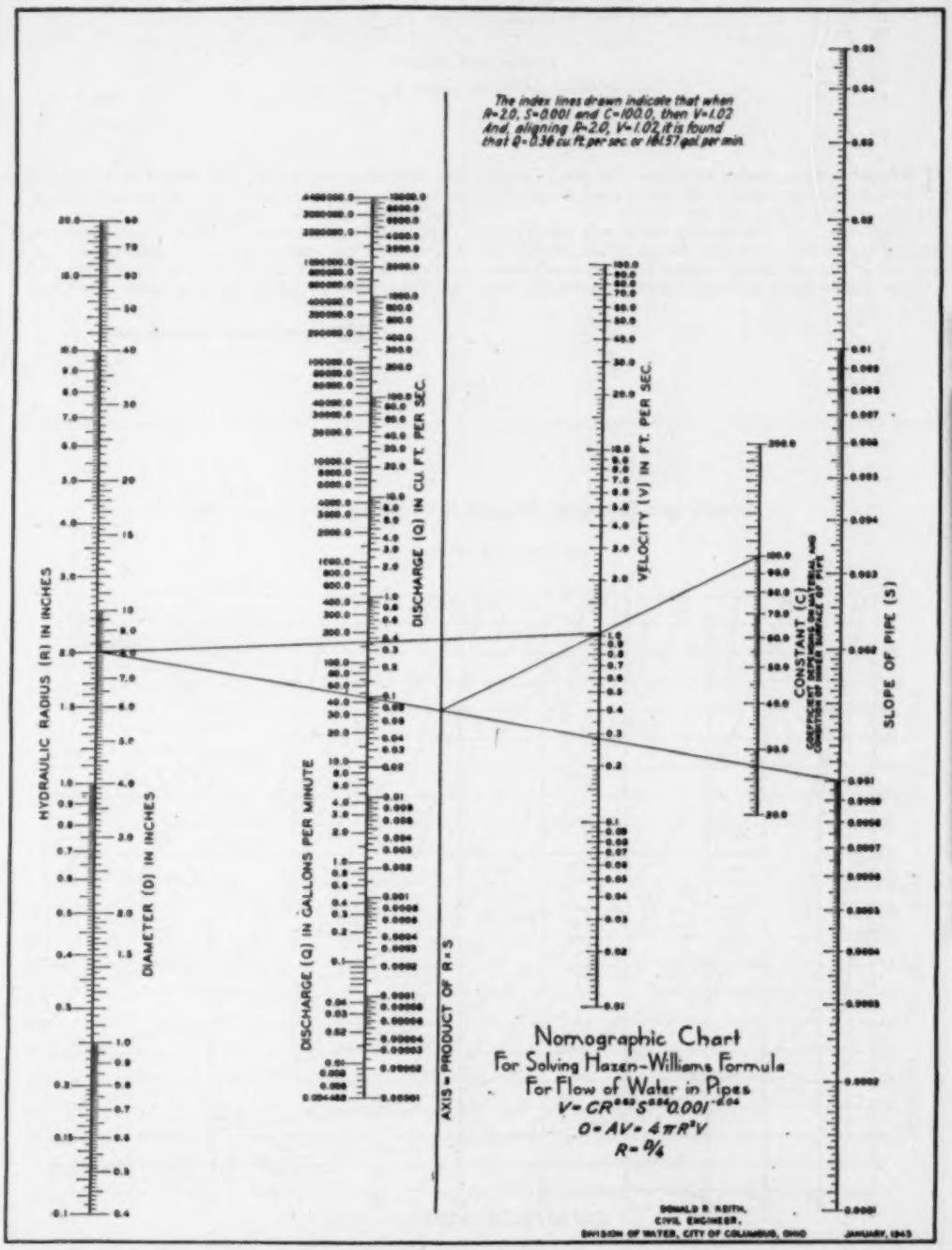
Values of "C" of course depend upon the material and condition of inner surface of pipe as noted on the accompanying chart. Tables showing values of "C" for various kinds of pipe, old and new, may be found in any hand-book of pipe data. For convenience of the user of the chart these values are listed in the following table:

"Hazen-Williams Table of Values for 'C.'"

Cast Iron Pipe, very smooth	140 to 145
" " " new, good condition	125 to 138
" " " old, good condition	100 to 125
" " " old, bad condition	60 to 100
Steel Pipe, riveted new	105 to 115
" " riveted old	90 to 105
Masonry Conduits	110 to 135
Brass, block tin, lead, glass	140 to 150

NUMBER OF TAPS THAT CAN BE TAKEN FROM PIPE OF VARIOUS SIZES

Diameter of Pipe in Inches	SIZE OF TAPS IN INCHES																						
	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15	16	18	20	22	24
2	11	5	3	2	1																			
2½	20	9	5	3	1	1																		
3	32	15	8	5	2	1	1																	
3½	47	22	13	8	4	2	1	1																
4	65	32	18	11	5	3	2	1	1															
4½	88	42	24	15	7	4	2	1	1	1														
5	114	55	32	20	9	5	3	2	1	1	1													
6	181	88	50	32	15	8	5	3	2	2	1	1												
7	266	129	74	47	22	13	8	5	4	3	2	1	1											
8	371	181	103	65	32	18	11	7	5	4	3	2	1	1										
9		243	139	88	42	24	15	10	7	5	4	2	1	1	1									
10		316	181	114	55	32	20	13	9	7	5	3	2	1	1	1								
12			285	181	88	50	32	21	15	11	8	5	3	2	2	1	1							
14			419	266	129	74	47	32	22	17	13	8	5	4	3	2	1	1						
15				316	154	88	55	38	27	20	15	9	6	4	3	2	1	1	1					
16				371	181	103	65	44	32	23	18	11	7	5	4	3	2	1	1	1				
18					243	139	88	59	42	32	24	15	10	7	5	4	2	1	1	1	1			
20					316	181	114	78	55	41	32	20	13	9	7	5	3	2	2	1	1	1		
22						229	145	99	70	52	40	25	17	12	9	7	4	3	2	2	1	1	1	
24						285	181	123	88	65	50	32	21	15	11	8	5	3	3	2	2	1	1	1


The index lines drawn indicate that when R=2.0, S=0.001 and C=100.0, then V=1.02
And, aligning R=2.0, V=1.02 it is found that Q=0.36 cu ft per sec or 161.57 gal per min.
HYDRAULIC RADIUS (R) IN INCHES
DIAMETER (D) IN INCHES
DISCHARGE (Q) IN GALLONS PER MINUTE
DISCHARGE (Q) IN CU. FT. PER SEC.
AXIS = PRODUCT OF R·S
VELOCITY (V) IN FT. PER SEC.
CONSTANT (C)
SLOPE OF PIPE (S)
Nomographic Chart
For Solving Hazen-Williams Formula
For Flow of Water in Pipes
$V = CR^{0.63}S^{0.54}0.001^{-0.04}$
$Q = AV = 4\pi R^2 V$
$R = D/4$
DONALD R. KEITH,
CIVIL ENGINEER,
DIVISION OF WATER, CITY OF COLUMBUS, OHIO
JANUARY, 1943

Directions for using chart: Place straightedge on "D" scale at pipe diameter in inches and on "S" scale at loss of head per foot of pipe. Determine point on "Axis" line where straightedge crosses. Then place straightedge on this point on the Axis line and at Constant "C" for the pipe in question. Determine point where straightedge then crosses Velocity "V" scale. Next place straightedge on this point on "V" scale and on diameter of pipe in inches on "D" scale. Read Discharge "Q" in cfs or gpm where straightedge crosses "Q" line.

NOMOGRAPH FOR SOLVING MANNING'S FORMULA

By PAUL McH. ALBERT

Drury, McNamee and Porter, Engrs., Ann Arbor, Mich.

THE accompanying nomographic chart presents a simple, rapid, and practical means of solving Manning's Formula for the flow of water in pipes and open channels.

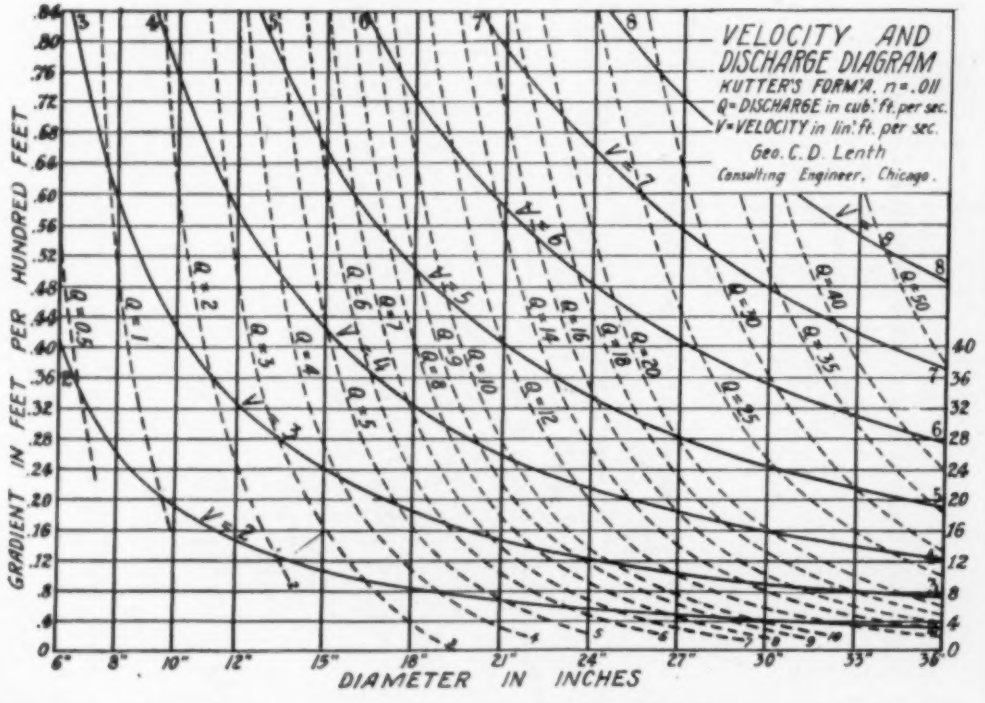
Snap analysis of problems involving this formula will be more accurate and quicker when using this nomograph inasmuch as only two or three motions are required to arrive at an answer.

If the problem entails considerable study, many different solutions may be rapidly tabulated. The effect of the coefficient "n" on the other variables as determined from the nomograph is a valuable aid for the entire range is included.

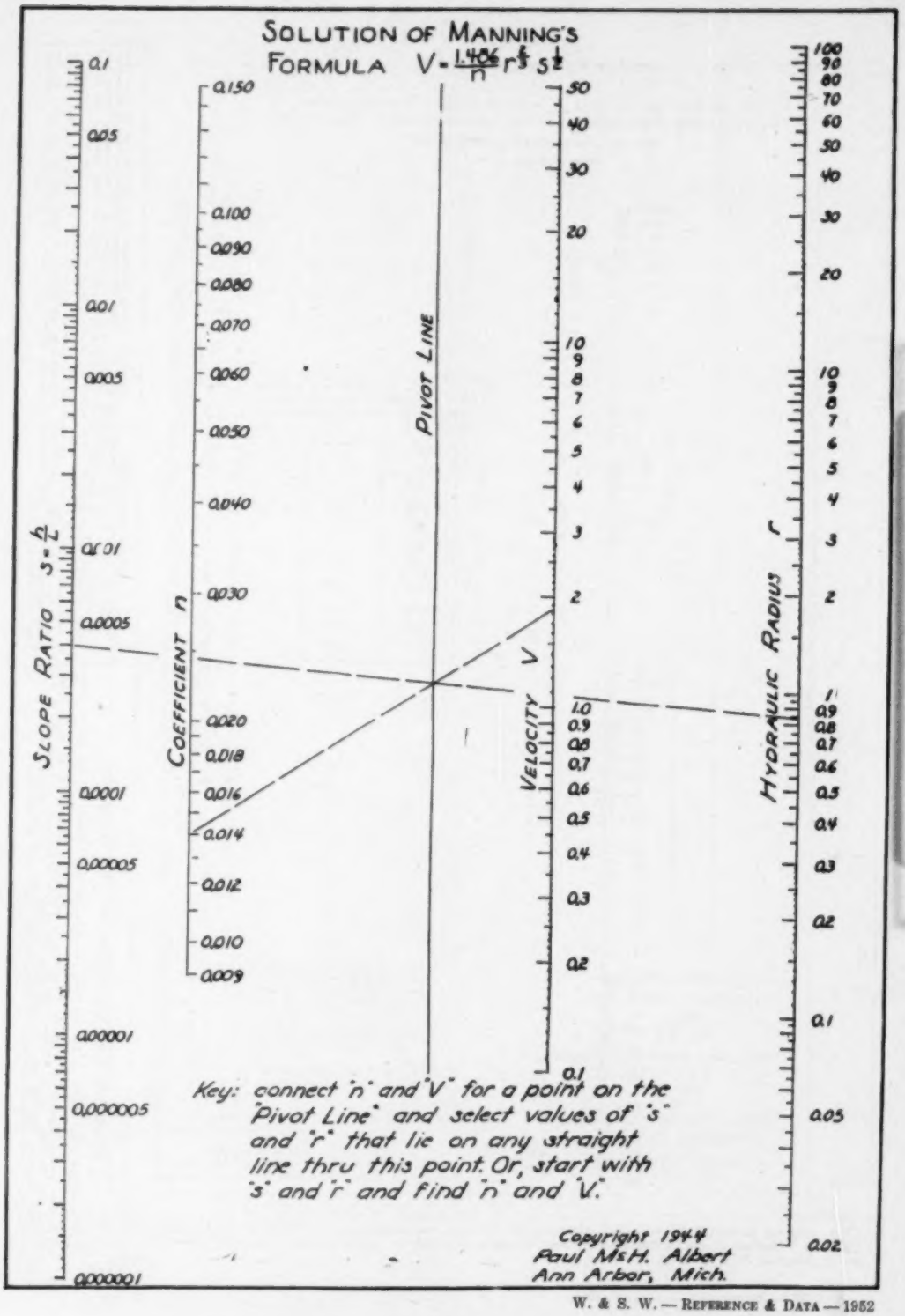
For use in checking previous designs this chart will be found to be valuable and make possible rapid checks inasmuch as it covers a wide range of all the variables. Directions for using the nomograph are given in the key at the bottom of the chart.

Velocity and Discharge Diagram for Vitrified Clay Sewer Pipe

(Courtesy, Clay Products Assn.)


VELOCITY AND DISCHARGE DIAGRAM
KUTTER'S FORMA. n=.011
Q=DISCHARGE in cub'. ft. per sec.
V=VELOCITY in lin'. ft. per sec.
Geo. C. D. Lenth
Consulting Engineer, Chicago.
GRADIENT IN FEET PER HUNDRED FEET
DIAMETER IN INCHES
6" 8" 10" 12" 15" 18" 21" 24" 27" 30" 33" 36"

(Example: Assume 12 cu. ft. per sec. as the flow to be handled. The gradient for instance, to be a 0.2 ft. per 100 ft. run. Follow to right from gradient figure 0.20 on left until Q12 dotted line is intersected. The vertical line found at that point indicates that a 24 inch sewer is required. Also from the nearest velocity curve V.A at the intersection it is revealed that the velocity will be 3.8 ft. at full or half full flow.)

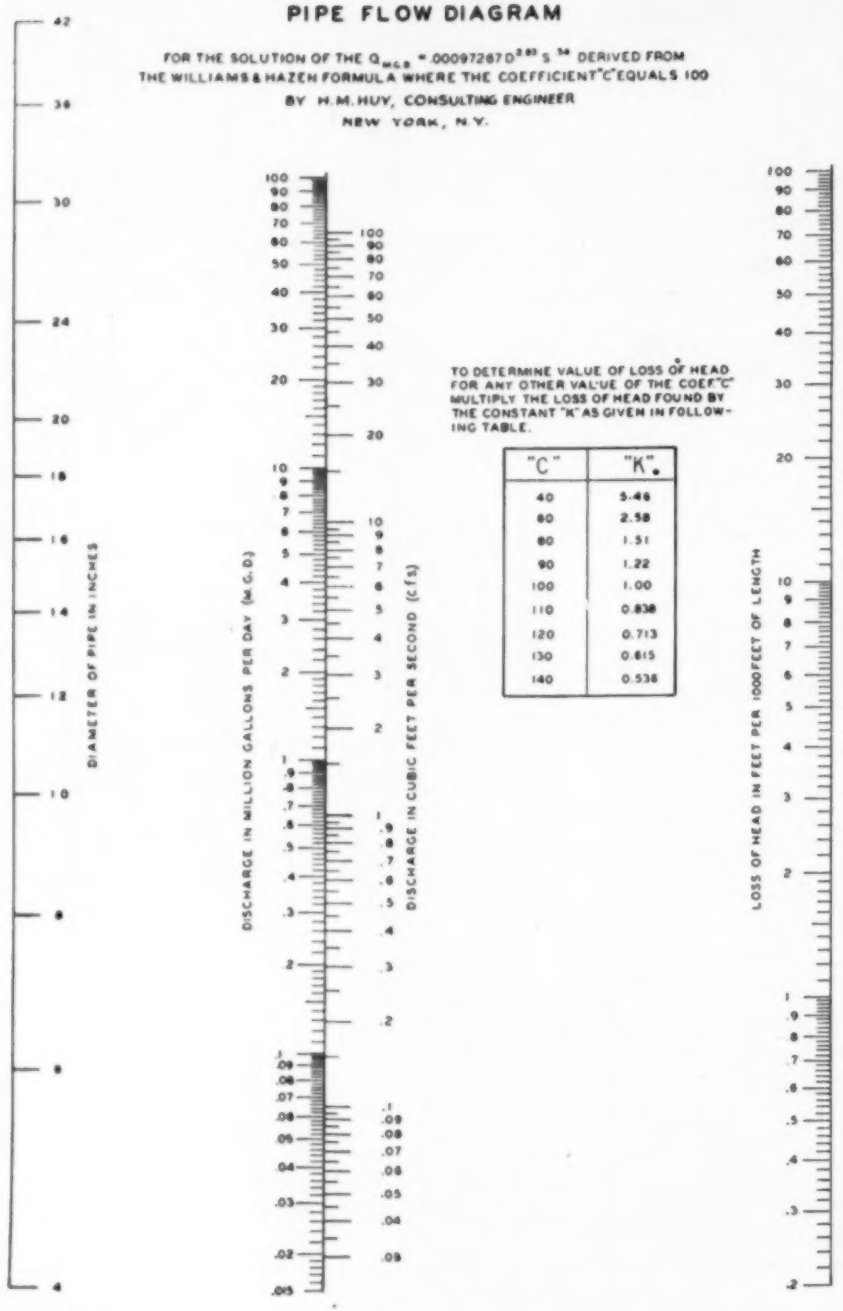

SOLUTION OF MANNING'S FORMULA V = 1.486/n r^⅔ s^½
SLOPE RATIO s = h/l
COEFFICIENT n
PIVOT LINE
VELOCITY V
HYDRAULIC RADIUS r
Key: connect "n" and "V" for a point on the "Pivot Line" and select values of "s" and "r" that lie on any straight line thru this point. Or, start with "s" and "r" and find "n" and "V".
Copyright 1944
Paul M. & H. Albert
Ann Arbor, Mich.

PIPE FLOW DIAGRAM

FOR THE SOLUTION OF THE $Q_{M.G.D.} = .00097287 D^{2.63} S^{.54}$ DERIVED FROM THE WILLIAMS & HAZEN FORMULA WHERE THE COEFFICIENT "C" EQUALS 100

BY H. M. HUY, CONSULTING ENGINEER

NEW YORK, N.Y.



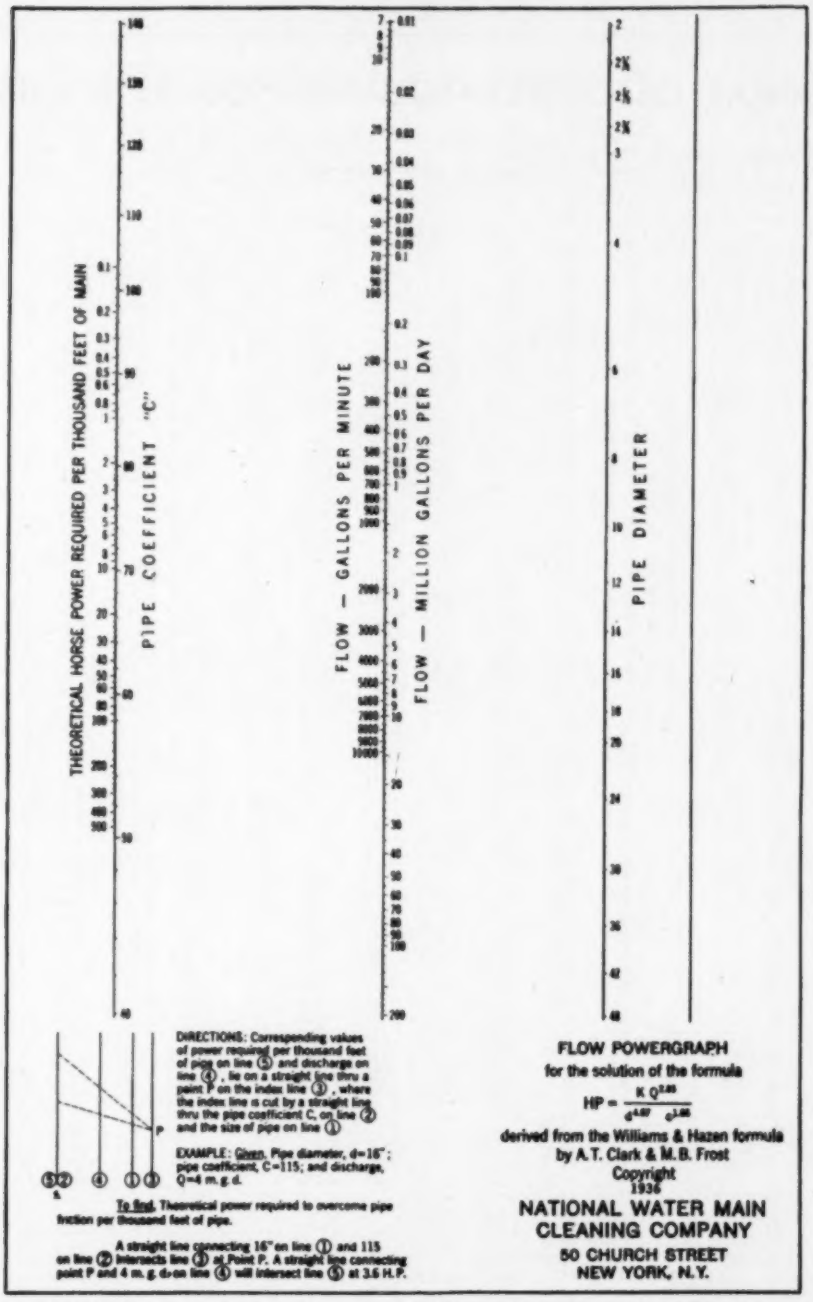
TO DETERMINE VALUE OF LOSS OF HEAD FOR ANY OTHER VALUE OF THE COEF. "C" MULTIPLY THE LOSS OF HEAD FOUND BY THE CONSTANT "K" AS GIVEN IN FOLLOWING TABLE.

"C"	"K"
40	5.46
60	2.58
80	1.51
90	1.22
100	1.00
110	0.838
120	0.713
130	0.615
140	0.536

Directions for Application of This Diagram

(a) **FRICTION-HEAD LOSS:** A line run from pipe diameter (left vertical) through M.G.D. rate of flow (center) intersects friction vertical (right) to reveal computed friction loss per 1,000 ft. of pipeline; the capacity of the same pipeline to produce a specified friction loss per 1,000 ft. is revealed if the friction value is known

Flow Powergraph


THEORETICAL HORSE POWER REQUIRED PER THOUSAND FEET OF MAIN
PIPE COEFFICIENT "C"
FLOW — GALLONS PER MINUTE
FLOW — MILLION GALLONS PER DAY
PIPE DIAMETER
DIRECTIONS: Corresponding values of power required per thousand feet of pipe on line (5) and discharge on line (4), lie on a straight line thru a point P on the index line (3), where the index line is cut by a straight line thru the pipe coefficient C, on line (2) and the size of pipe on line (1)
EXAMPLE: Given, Pipe diameter, d=16"; pipe coefficient, C=115; and discharge, Q=4 m.g.d.
To find, Theoretical power required to overcome pipe friction per thousand feet of pipe.
A straight line connecting 16" on line (1) and 115 on line (2) intersects line (3) at Point P. A straight line connecting point P and 4 m. g. d.-on line (4) will intersect line (5) at 3.6 H.P.
FLOW POWERGRAPH
for the solution of the formula
$HP = \frac{K\,Q^{1.85}}{d^{4.87}\ c^{1.85}}$
derived from the Williams & Hazen formula
by A.T. Clark & M.B. Frost
Copyright
1936
NATIONAL WATER MAIN CLEANING COMPANY
50 CHURCH STREET
NEW YORK, N.Y.

This Highly Useful Graph Was Devised by Arthur T. Clark and M. B. Frost for Simplified Determination of Power Required to Overcome Pipe Friction Under Various Conditions. Also to Determine Condition of Pipe Lines in Service. (Copies of This Graph on Linen Are Being Distributed Gratis by National Water Main Cleaning Co., New York City.)

AREAS OF CIRCLES—SQUARES—SQUARE ROOTS

(Also Fractions to Decimal Equivalent.)

No. N Fraction	No. N Decimal	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
1/16	.0625	.0039	.2500	.0031
1/8	.125	.0156	.3536	.0125
3/16	.1875	.0352	.4330	.0276
1/4	.25	.0625	.5000	.0491
5/16	.3125	.0977	.5590	.0767
3/8	.375	.1406	.6124	.1105
7/16	.4375	.1914	.6614	.1503
1/2	.50	.2500	.7071	.1964
9/16	.5625	.3164	.7500	.2485
5/8	.625	.3906	.7906	.3068
11/16	.6875	.4727	.8292	.3712
3/4	.75	.5625	.8660	.4418
13/16	.8125	.6602	.9014	.5185
7/8	.875	.7656	.9354	.6013
15/16	.9375	.8789	.9683	.6903
1	1.	1.000	1.000	.7854
1 1/16	1.125	1.266	1.061	.9940
1 1/4	1.25	1.563	1.118	1.227
1 3/8	1.375	1.891	1.175	1.485
1 1/2	1.50	2.250	1.225	1.767
1 5/8	1.625	2.641	1.275	2.074
1 3/4	1.75	3.063	1.323	2.405
1 7/8	1.875	3.516	1.369	2.761
2	2.	4.000	1.414	3.142
2 1/8	2.125	4.516	1.458	3.547
2 1/4	2.25	5.063	1.500	3.976
2 3/8	2.375	5.641	1.541	4.430
2 1/2	2.50	6.250	1.581	4.909
2 5/8	2.625	6.891	1.620	5.412
2 3/4	2.75	7.563	1.658	5.940
2 7/8	2.875	8.266	1.696	6.492
3	3.	9.000	1.732	7.069
3 1/8	3.125	9.766	1.768	7.670
3 1/4	3.25	10.56	1.803	8.296
3 3/8	3.375	11.39	1.837	8.946
3 1/2	3.50	12.25	1.871	9.621
3 5/8	3.625	13.14	1.904	10.32
3 3/4	3.75	14.06	1.937	11.04
3 7/8	3.875	15.02	1.969	11.79
4	4.	16.00	2.000	12.57
4 1/8	4.125	17.02	2.031	13.36
4 1/4	4.25	18.06	2.062	14.19
4 3/8	4.375	19.14	2.092	15.03
4 1/2	4.50	20.25	2.121	15.90
4 5/8	4.625	21.39	2.151	16.80
4 3/4	4.73	22.56	2.180	17.72
4 7/8	4.875	23.77	2.208	18.67
5	5.00	25.00	2.236	19.64
5 1/8	5.25	27.56	2.291	21.65
5 1/2	5.50	30.25	2.345	23.76
5 3/4	5.75	33.06	2.398	25.97
6	6.	36.00	2.450	28.27
6 1/4	6.25	39.06	2.500	30.68
6 1/2	6.50	42.25	2.550	33.18
6 3/4	6.75	45.56	2.598	35.78
7	7.	49.00	2.646	38.48
7 1/4	7.25	52.56	2.693	41.28
7 1/2	7.50	56.25	2.739	44.18
7 3/4	7.75	60.06	2.784	47.17
8	8.00	64.00	2.828	50.27
8 1/4	8.25	68.06	2.872	53.46
8 1/2	8.50	72.25	2.916	56.75
8 3/4	8.75	76.56	2.958	60.13
9	9.00	81.00	3.000	63.62
9 1/4	9.25	85.56	3.041	67.20
9 1/2	9.50	90.25	3.082	70.88
9 3/4	9.75	95.06	3.123	74.66

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
10	100	3.162	78.54
11	121	3.317	95.03
12	144	3.464	113.1
13	169	3.606	132.7
14	196	3.742	153.9
15	225	3.873	176.7
16	256	4.000	201.1
17	289	4.123	227.0
18	324	4.243	254.5
19	361	4.359	283.5
20	400	4.472	314.2
21	441	4.583	346.4
22	484	4.690	380.1
23	529	4.796	415.5
24	576	4.899	452.4
25	625	5.000	490.9
26	676	5.099	530.9
27	729	5.196	572.6
28	784	5.292	615.8
29	841	5.385	660.5
30	900	5.477	706.9
31	961	5.568	754.8
32	1024	5.657	804.2
33	1089	5.745	855.3
34	1156	5.831	907.9
35	1225	5.916	962.1
36	1296	6.000	1017.9
37	1369	6.083	1075.2
38	1444	6.164	1134.1
39	1521	6.245	1194.6
40	1600	6.325	1256.7
41	1681	6.403	1320.3
42	1764	6.481	1385.4
43	1849	6.557	1452.2
44	1936	6.633	1520.5
45	2025	6.708	1590.4
46	2116	6.782	1661.9
47	2209	6.856	1734.9
48	2304	6.928	1809.6
49	2401	7.000	1885.7
50	2500	7.071	1936.5
51	2601	7.141	2042.8
52	2704	7.211	2123.7
53	2809	7.280	2206.2
54	2916	7.349	2290.2
55	3025	7.416	2375.8
56	3136	7.483	2463.0
57	3249	7.500	2551.8
58	3364	7.616	2642.1
59	3481	7.681	2734.0
60	3600	7.746	2827.4
61	3721	7.810	2922.5
62	3844	7.874	3019.1
63	3969	7.937	3117.2
64	4096	8.000	3217.0
65	4225	8.062	3318.3
66	4356	8.124	3421.2
67	4489	8.185	3525.7
68	4624	8.246	3631.7
69	4761	8.307	3739.3
70	4900	8.367	3848.5
71	5041	8.426	3959.2
72	5184	8.485	4071.5
73	5329	8.544	4185.4
74	5476	8.602	4300.8
75	5625	8.660	4417.9
76	5776	8.718	4536.5
77	5929	8.775	4656.6
78	6084	8.832	4778.4
79	6241	8.888	4901.7
80	6400	8.944	5026.5
81	6561	9.000	5153.0
82	6724	9.055	5281.0
83	6889	9.110	5410.6
84	7056	9.165	5541.8
85	7225	9.220	5674.5
86	7396	9.274	5808.8
87	7569	9.327	5944.7
88	7744	9.381	6082.1
89	7921	9.434	6221.1
90	8100	9.487	6361.7
91	8281	9.539	6503.9
92	8464	9.592	6647.6
93	8649	9.644	6792.9
94	8836	9.695	6939.8
95	9025	9.747	7088.2
96	9216	9.798	7238.2
97	9409	9.849	7389.8
98	9604	9.900	7543.0
99	9801	9.950	7697.7
100	10000	10.00	7854.0
101	10201	10.05	8011.9
102	10404	10.10	8171.3
103	10609	10.15	8332.3
104	10816	10.20	8494.9
105	11025	10.25	8659.0
106	11236	10.30	8824.7
107	11449	10.34	8992.0
108	11664	10.39	9160.9
109	11881	10.44	9331.3
110	12100	10.49	9503.3
111	12321	10.54	9676.9
112	12544	10.58	9852.0
113	12769	10.63	10029
114	12996	10.68	10207
115	13225	10.72	10387
116	13456	10.77	10568
117	13689	10.82	10751
118	13924	10.86	10936
119	14161	10.91	11122
120	14400	10.95	11310
121	14641	11.00	11499
122	14884	11.05	11690
123	15129	11.09	11882
124	15376	11.14	12076
125	15625	11.18	12272
126	15876	11.23	12469
127	16129	11.27	12668
128	16384	11.31	12868
129	16641	11.36	13070
130	16900	11.40	13273
131	17161	11.45	13478
132	17424	11.49	13685
133	17689	11.53	13893
134	17956	11.58	14103
135	18225	11.62	14314
136	18496	11.66	14527
137	18769	11.70	14741
138	19044	11.75	14957
139	19321	11.79	15175
140	19600	11.83	15394
141	19881	11.87	15615

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
142	20164	11.92	15837
143	20449	11.96	16061
144	20736	12.00	16286
145	21025	12.04	16513
146	21316	12.08	16742
147	21609	12.12	16972
148	21904	12.17	17203
149	22201	12.22	17437
150	22500	12.25	17671
151	22801	12.29	17908
152	23104	12.33	18146
153	23409	12.37	18385
154	23716	12.41	18627
155	24025	12.45	18869
156	24336	12.49	19113
157	24649	12.53	19359
158	24964	12.57	19607
159	25281	12.61	19856
160	25600	12.65	20106
161	25921	12.69	20358
162	26244	12.73	20613
163	26569	12.77	20867
164	26896	12.81	21124
165	27225	12.85	21382
166	27556	12.88	21642
167	27889	12.92	21904
168	28224	12.96	22168
169	28561	13.00	22432
170	28900	13.04	22698
171	29241	13.08	22966
172	29584	13.11	23235
173	29929	13.15	23506
174	30276	13.19	23779
175	30625	13.23	24053
176	30976	13.27	24328
177	31329	13.30	24606
178	31684	13.34	24885
179	32041	13.38	25165
180	32400	13.42	25447
181	32761	13.45	25730
182	33124	13.49	26016
183	33489	13.53	26302
184	33856	13.56	26590
185	34225	13.60	26880
186	34596	13.64	27172
187	34969	13.67	27465
188	35344	13.71	27759
189	35721	13.75	28055
190	36100	13.78	28353
191	36481	13.82	28652
192	36864	13.86	28953
193	37249	13.89	29255
194	37636	13.93	29559
195	38025	13.96	29865
196	38416	14.00	30172
197	38809	14.04	30481
198	39204	14.07	30791
199	39601	14.11	31103
200	40000	14.14	31416
...	.....	....	.....
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...	.....	....	.....

VELOCITY IN PIPES

Rate of Flow in Gals. per Min.	NOMINAL DIAMETER OF PIPE (Velocity in Feet Per Second)														Rate of Flow in Gals. per Min.
	¼"	⅜"	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	5"	6"		
1	5.68														1
2		3.08	1.67	1.05	1.20										2
3		4.16	3.35	2.10	1.80	1.12									3
4			5.02	3.16	2.41	1.49	0.86	0.63							4
5			6.70	4.21	3.01	1.86	1.07	0.79							5
10			8.37	5.26		3.72	2.14	1.57	1.02	0.65	0.45				10
15				10.52	6.02	5.60	3.21	2.36	1.53	0.98	0.68				15
20					9.02	7.44	4.29	3.15	2.04	1.31	0.91				20
25					12.03	9.30	5.36	3.94	2.55	1.63	1.13				25
30						11.15	6.43	4.72	3.06	1.96	1.36				30
35						13.02	7.51	5.51	3.57	2.29	1.58				35
40						14.88	8.58	6.30	4.08	2.61	1.82	1.02			40
45							9.65	7.08	4.60	2.94	2.04	1.15			45
50							10.72	7.87	5.11	3.27	2.27	1.28			50
70							15.01	11.02	7.15	4.58	3.18	1.79	1.14		70
75								11.80	7.66	4.90	3.40	1.92	1.22		75
100								15.74	10.21	6.54	4.54	2.55	1.63	1.10	100
120								18.89	12.25	7.84	5.45	3.06	1.96	1.36	120
125									12.75	8.16	5.66	3.19	2.04	1.42	125
150									15.32	9.80	6.80	3.84	2.45	1.70	150
175									17.85	11.40	7.94	4.46	2.86	1.98	175
200	8"								20.42	13.07	9.08	5.11	3.27	2.27	200
225	1.60									14.70	10.20	5.75	3.67	2.55	225
250	1.73									16.30	11.32	6.38	4.08	2.84	250
270											12.25	6.90	4.41	3.06	270
275	1.76										12.50	7.03	4.49	3.12	275
300	1.92										13.62	7.66	4.90	3.40	300
350	2.24	10"										8.94	5.72	3.98	350
400	2.56											10.21	6.54	4.54	400
450	2.88	1.84										11.49	7.35	5.11	450
470	3.01	1.92	12"									12.00	7.68	5.34	470
475	3.04	1.94										12.10	7.75	5.40	475
500	3.20	2.04	1.42									12.77	8.17	5.68	500
550	3.52	2.25	1.56										8.99	6.24	550
600	3.84	2.45	1.70	14"									9.80	6.81	600
650	4.16	2.65	1.85	1.30									10.62	7.38	650
700	4.48	2.86	1.99	1.40									11.44	7.94	700
750	4.80	3.06	2.13	1.50									12.26	8.50	750
800	5.12	3.27	2.27	1.60										9.08	800
850	5.45	3.47	2.41	1.70	15"									9.65	850
900	5.76	3.67	2.56	1.80	1.67									10.20	900
950	6.08	3.88	2.70	1.90	1.76									10.77	950
1000	6.40	4.08	2.84	2.00	1.85									11.34	1000
1050	6.72	4.29	2.98	2.10	1.93									11.90	1050
1100	7.04	4.49	3.13	2.20		16"								12.48	1100
1150	7.36	4.70	3.27	2.30	2.02									13.05	1150
1200	7.68	4.90	3.41	2.40	2.11	1.99								13.61	1200
1250	8.00	5.41	3.56	2.50	2.20	2.09								14.29	1250
1500	9.60	6.12	4.26	3.05	2.64	3.09									1500
2000	12.80	8.10	5.68	4.00	3.52		20"								2000
2500		10.20	7.10	5.01	4.40	3.98	3.07	24"							2500
3000		12.24	8.52	6.01	5.28	4.78	3.53	2.43	30"						3000
3500		14.50	9.95	7.02	6.16	5.58	4.10	2.83	1.81						3500
4000			11.36	8.02	7.04	6.33	4.30	2.97	1.90						4000
4200			11.92	8.42	7.40	6.70									4200
4500			12.78	9.02	7.92	7.17	4.61	3.19	2.04	36"					4500
5000			14.20	10.02	8.80	7.96	5.12	3.54	2.26						5000
5500				11.01	9.69	8.77	5.63	3.90	2.49	1.57					5500
6000				12.00	10.56	9.56	6.14	4.25	2.72	2.05					6000
6500				13.00	11.44	10.36	6.66	4.60	2.94						6500
7000				14.02	12.32	11.16	7.16	4.97	3.17	2.21					7000
7200					13.20	11.50	7.38	5.16	3.26	2.27					7200
7500					14.00	11.96	7.68	5.32	3.40	2.37					7500
8000							8.20	5.66	3.62	2.52					8000
8500							8.70	6.02	3.85	2.68					8500
9000							9.21	6.38	4.08	2.84	42"				9000
9500							9.72	6.72	4.31	3.00					9500
10000							10.24	7.08	4.58	3.15	2.31				10000
10500								7.44	4.76	3.30	2.43				10500
11000								7.79	4.99	3.46	2.55				11000
11500								8.15	5.28	3.62	2.66				11500
12000								8.50	5.44	3.78	2.78				12000
12500								8.85	5.67	3.93	2.89				12500
13000								9.20	5.90	4.00	3.01				13000
13500								9.56	6.12	4.25	3.13				13500

This table is taken from "Hydraulic Data," published by Gould's Pumps, Inc.

CONSOLIDATED REFERENCE AND DATA INDEX 1947 through 1952

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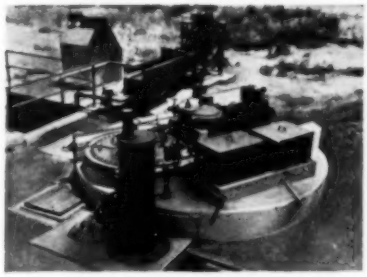
VERSATILE...

is the word for the Dorrco Vacuator*

Here are Three Ways it can be utilized to solve your problems...

AS A PRE-TREATMENT UNIT

1 At overflow rates of 5000 to 7500 gal./sq. ft./24 hrs., the Vacuator can serve as a complete pre-treatment unit, removing scum, grit and a substantial percentage of suspended solids—also thickening excess secondary sludges.



EXAMPLE:

At McAlester, Oklahoma's new West Sewage Treatment Plant a 12' dia. Vacuator removes scum, grease and grit from incoming screened sewage, prior to two-stage trickling filter treatment. Operating results show removals of 46.6% of suspended solids and a 28.4% reduction in B.O.D.

AS A SCUM-REMOVAL UNIT

2 At overflow rates of 5000 gal./sq. ft./24 hrs., the Vacuator can be used for the treatment of oil, cannery, packing house, laundry and similar tough-to-handle wastes.

EXAMPLE:

Scum-forming cannery wastes virtually put the Palo Alto, California Sewage Treatment Plant out of commission five months of the year. A 35' dia. Vacuator, followed by secondary treatment, completely solved the problem by removing an average of 43.6% of suspended solids, 58% of settleable solids and 8.4% of B.O.D. during the canning season.

AS A GREASE-REMOVAL UNIT

3 Overflow rates as high as 10,000 gal./sq. ft./24 hrs. can be used when the primary function of the Vacuator is grease removal from domestic or industrial wastes.

EXAMPLE:

At Patuxent River, Maryland, a 14' dia. Vacuator removes heavy "slug loads" of grease ahead of primary treatment. Removals average 50% of suspended solids and a 51% reduction in B.O.D., enabling the standard Dorr Clarifier which follows to function smoothly without auxiliary equipment.

These examples illustrate but three of the many ways in which the compact, three-product Vacuator is successfully solving difficult problems. If you think vacuum-flotation could help you, write for Bulletin #6301.

*Reg. U.S. Pat. Off.

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IN W&T CHLORINATORS, TOO!

When you look at a single W&T Chlorinator you can't *see* the basic research, the complete line of equipment, and the service that are behind it.

For instance, the engineer, the plant operator and the taxpayer all benefit from W&T's complete line of equipment. In the selection of equipment for a water supply — large or small — the engineer can always find a W&T Chlorinator to fit the requirements. The plant operator knows that this complete line can provide a W&T Chlorinator designed to help him provide safe water with his particular plant layout. The taxpayer is assured that money spent for W&T Equipment fitted to the present as well as the future needs of his community will provide long range economy.

These advantages of W&T's wide selection of equipment are probably one reason so many people use W&T Chlorinators.

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